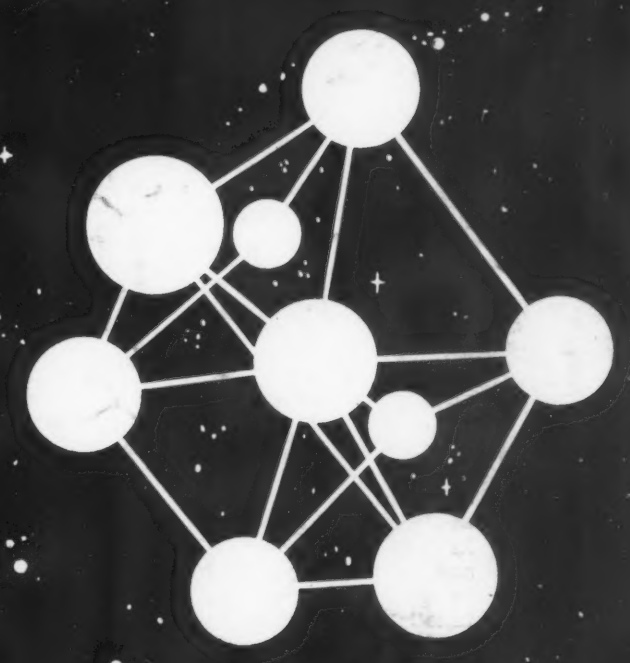
NUCLEAR ENERGY

THE JOURNAL OF THE INSTITUTION OF NUCLEAR ENGINEERS



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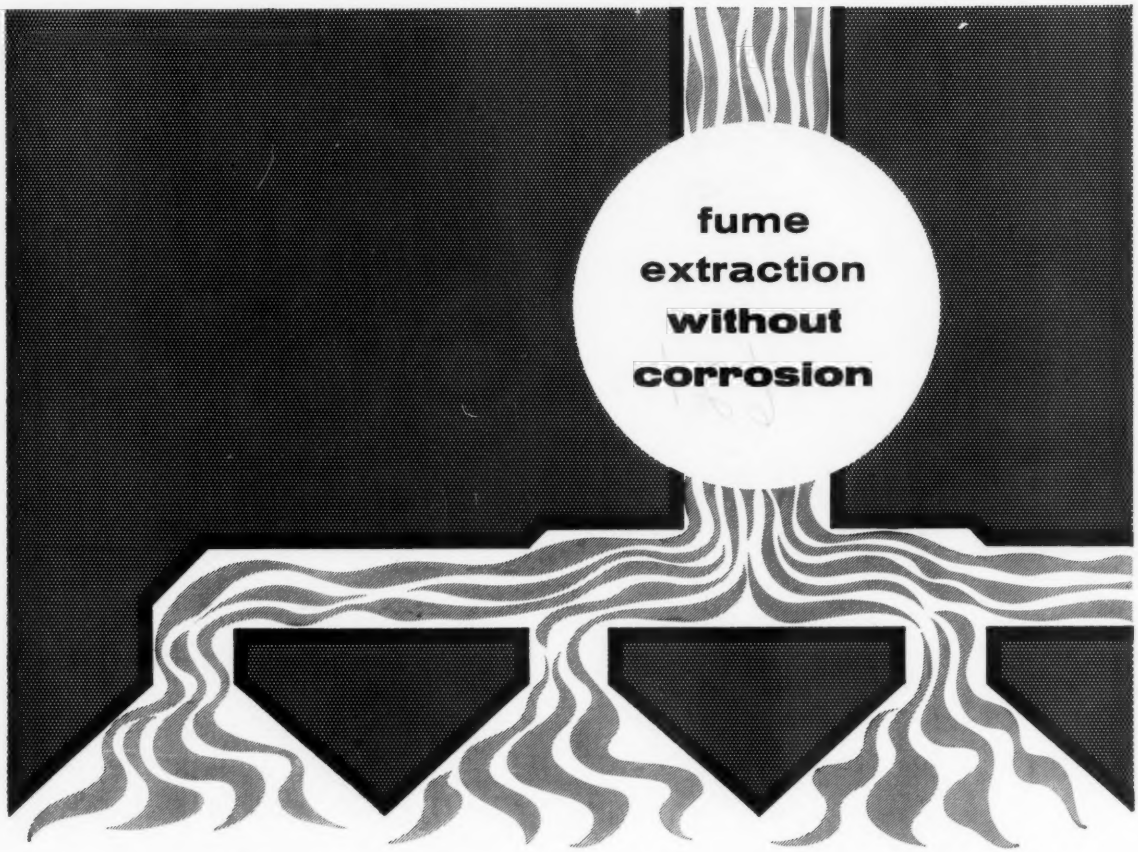

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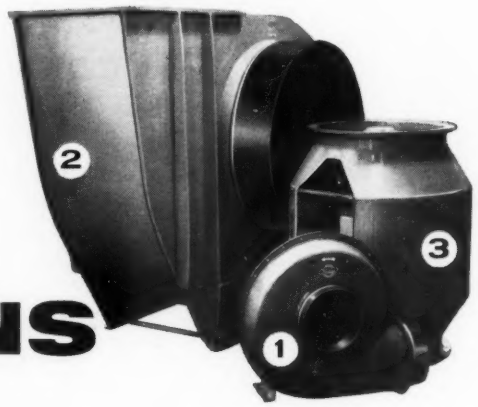

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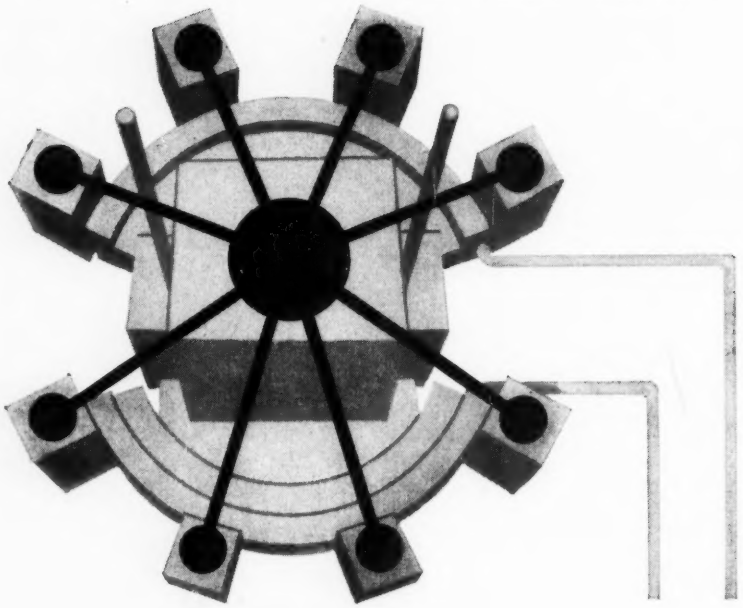
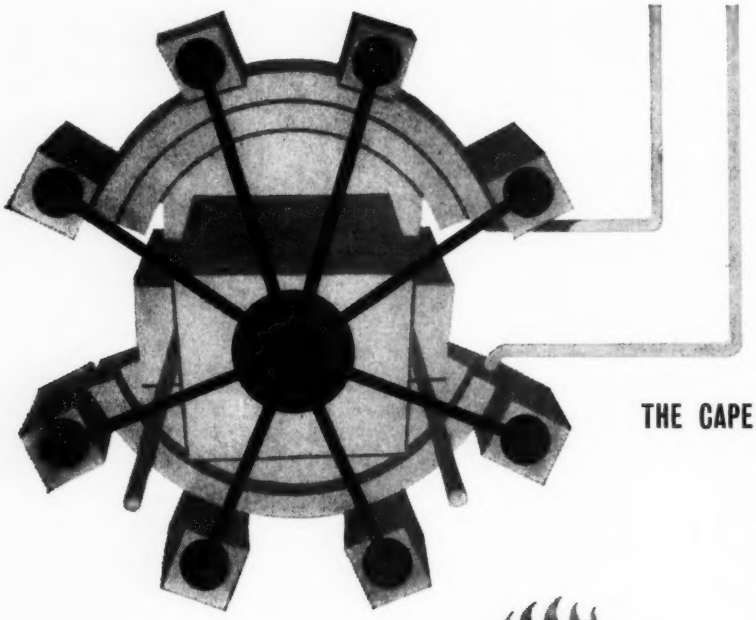


BERKELEY—a challenge to insulation



The heat developed by the twin reactors of the new Berkeley atomic power station poses problems of thermal insulation which will require new techniques in their solution. Confining and controlling such intense yet precious thermal energy constitutes a challenge—a test worthy of the knowledge and skill acquired in 65 years' experience of thermal insulation manufacture by The Cape Asbestos Company, to whom the contract has been entrusted.

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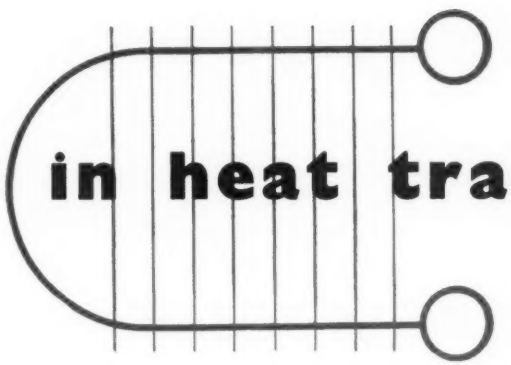

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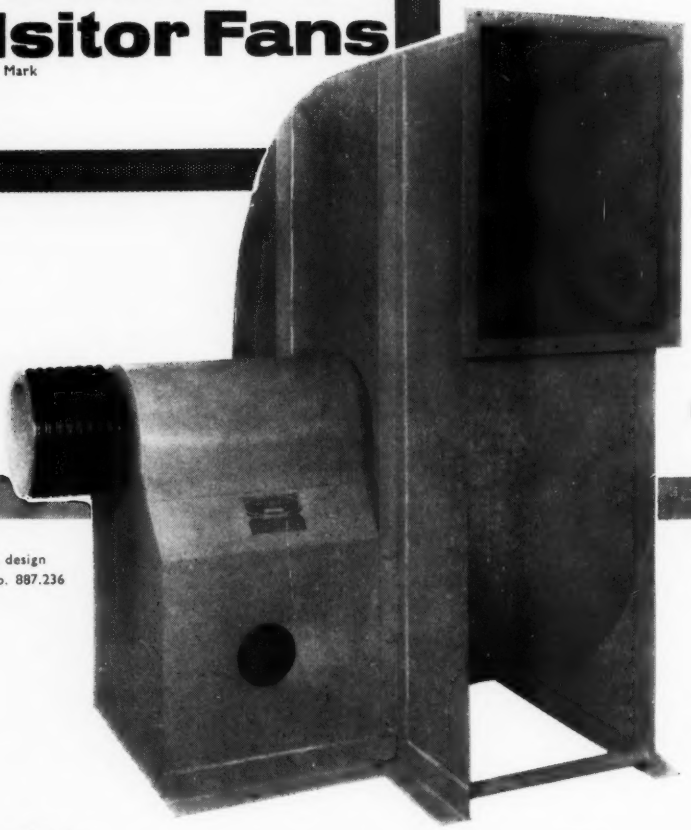

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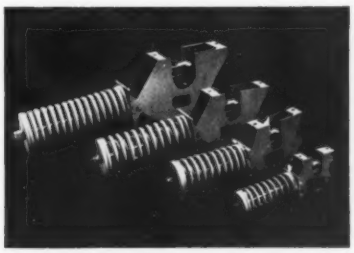
"I'm a belt and braces man, myself"

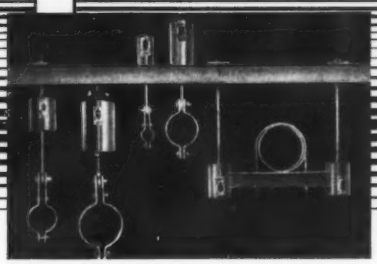
"Because I wear both, my mates reckon I'm a bit of a pessimist! But when it's a matter of essential support I'd rather be safe than sorry. Likewise, I've rigged enough to know that pipework suspended from Gensprings is never going to give any trouble. They use Gensprings on the big nuclear stuff!

This small one just above my head is an M2 Constant Support Hanger. There's a range of sizes to deal with loads from 315 lb. to 97,800 lb. Maximum deviation—if you need it this exact—can now be guaranteed at not more than 2%.

Then there are the Variable Supports for jobs less critical than those needing "Constants", and then again there are Sway Braces for damping out shock and vibration. I'm beginning to sound like the catalogues that Vokes Genspring will be glad to send you!"



Vokes Genspring 'M' Range Constant Support Hangers for supporting pipework and other high temperature equipment such as heat exchangers, furnace walls, condensers, etc. The constant supporting effort is equal to the weight of the pipework irrespective of thermal movements.



The Vokes Genspring range of Variable Supports covers travel ranges of 1½", 3" and 6", and there are 16 sizes in each range, covering loads from 58 lb. to 13,790 lb.

Vokes Genspring Non-Resonant Sway Braces can control all pipework subject to vibration and normal thermal expansion. Eight spring sizes cover loads from 39 lb. to 1,500 lb.

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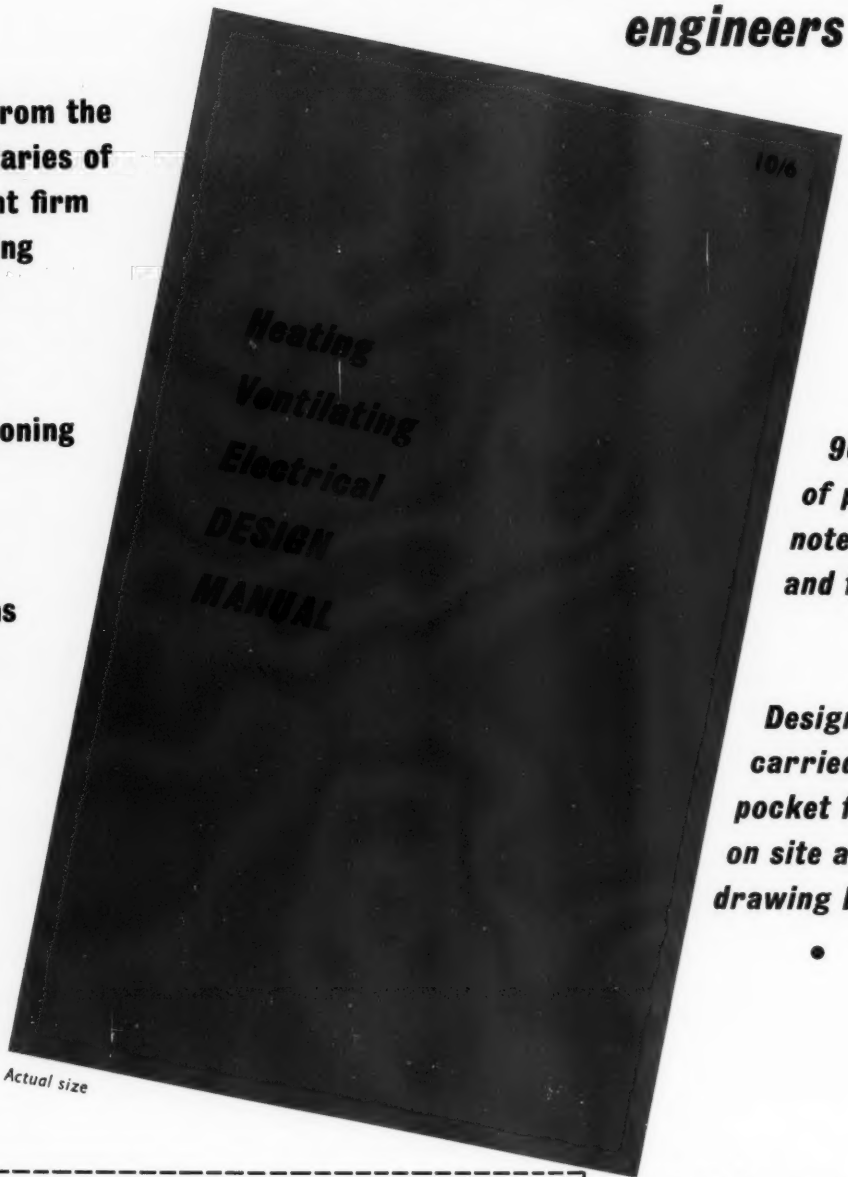

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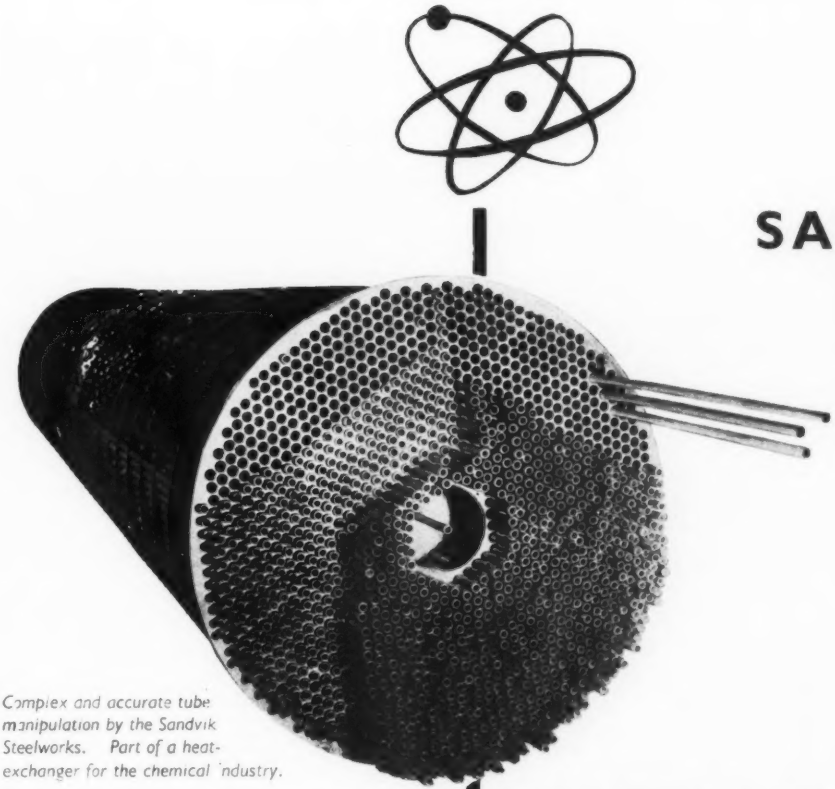

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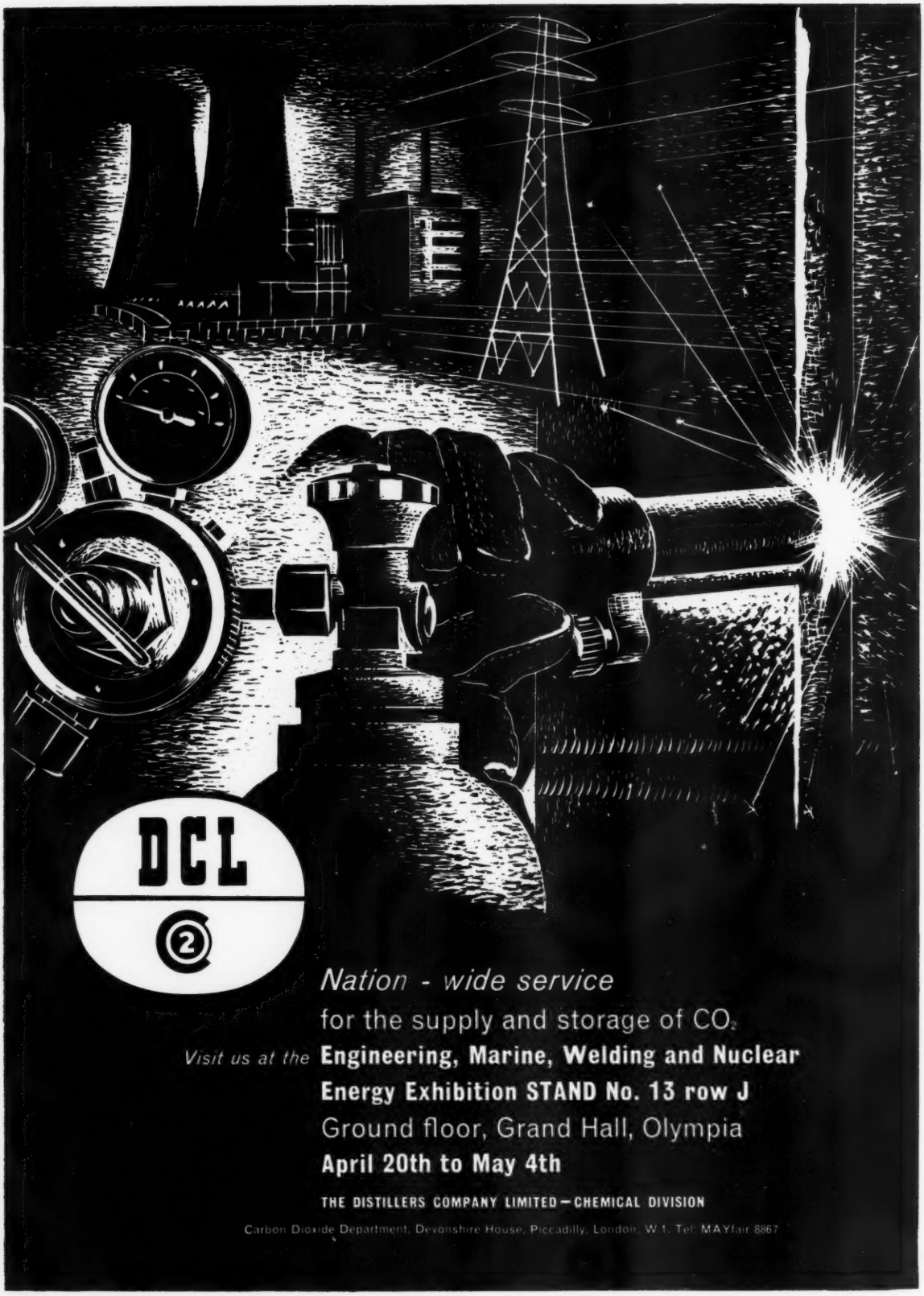
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APRIL 1961

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ISOTOPE WORLD

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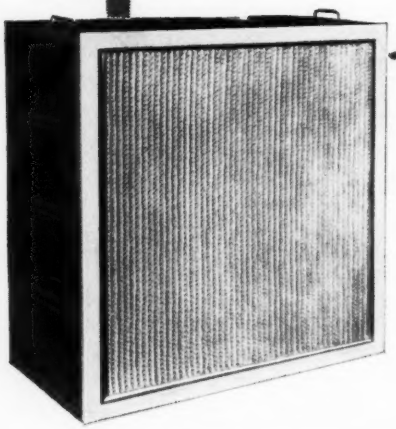
A speck of dust 1/10,000 of a millimetre in size has only one chance in 10,000 of getting past this Vokes 'Absolute' Filter



Other filters in Vokes 'Absolute' range include the standard type (guaranteed 99·95% efficient against sub-micronic particles) and high humidity and acid resistant types (guaranteed 99·99% efficient against sub-micronic particles).

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Vokes 'Absolute' high temperature filters were developed for critical applications involving risk of fire, or temperatures up to 1000 F. They have proved particularly valuable in the filtration systems of nuclear power stations where a breakdown caused by an outbreak of fire might release dangerous toxic particles to atmosphere.

These filters have a guaranteed *minimum* efficiency of 99·99% against particles in the 0·1 to 0·5 micron range: therefore impurities in the air ranging in size from a ten thousandth of a millimetre to a two thousandth of a millimetre have only one chance in ten thousand of passing through the high temperature 'Absolute' all glass paper filter medium.

In addition Vokes *guarantee* the accuracy of these figures. As with all Vokes 'Absolute' filters, every high temperature type is tested in accordance with BSS 2831 on a methylene blue test rig and rejected if its efficiency is below the required standard.

You are invited to write for a booklet covering the range of Vokes special purpose air filters and containing details of Vokes unique testing methods.

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Classroom and Laboratory

Arising out of a proposal by Dr. F. R. Paulsen, at a Council Meeting of the Institution of Nuclear Engineers, several hundred teachers of nuclear science were asked to report on simple apparatus and methods used or those which might be useful for practical demonstrations in instructional courses. The response was enthusiastic. From all parts of the world, from teachers in Universities, High Schools and Colleges, from research workers, manufacturers and public relations experts, have come many ideas. As a service to teachers, and also to other workers in nuclear fields, we are now publishing the many suggestions put forward. Each suggestion carries the identity of the person who put it forward, and also a reference number. The latter will facilitate enquiries sent in by readers requiring further information. Readers are invited to submit suggestions for inclusion in this feature

No. 30 Alpha radiation source from clocks

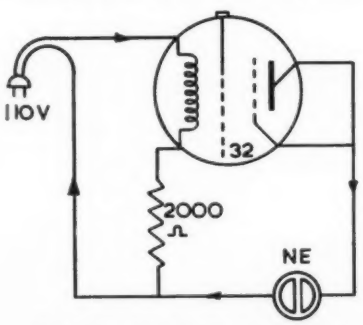
Joe W. Tyson, U.S.A.

An alpha radiation source can be obtained from radioactive luminous dials on watches and clocks. The luminous material is carefully scraped off, great care being taken to see that none of the powder is ingested by breathing. Gloves should be worn. The powder is mixed with a little rubber solution, such as is used in mending punctures in tyres, and stirred with the eye of a sewing needle. Some of the mixture will be retained in the eye of the needle. Allow the mixture to dry, then force the point of the needle into a cork and insert this into a test-tube or bottle which will protect the alpha radiation source.

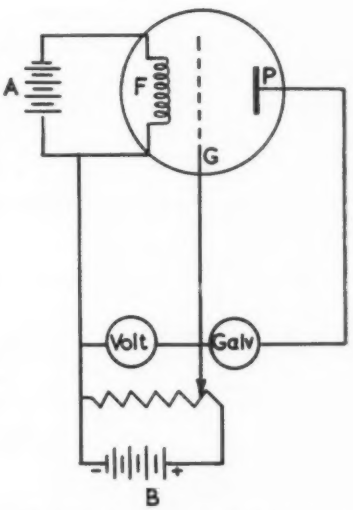
No. 31 Ionization potentials

George A. Scherer, U.S.A.

A simple apparatus for demonstrating ionization potentials can be built for about $3. A Type 32 radio valve using a 2,000 ohm, 10w resistor in series with the filament, operates from a 110v d.c. supply. The plate of the valve is connected to a 2w neon glow lamp, which is also joined to the end of the resistor remote from the filament. This lamp causes a glow in the plate emitting the electrons, as neon atoms are ionized. If a rod carrying a negative charge (*e.g.*, a stick of sealing-wax rubbed with wool) is brought near the grid cap, the neon lamp glow becomes fainter as the electron flow is impeded, while the approach of a positive charge (*e.g.*, a glass rod rubbed with silk) causes a brighter glow. The grid bias may also be produced by connecting small dry cells between the filament and the control grid. When the grid potential is several volts above that of the filament, the neon light is bright; when the grid potential is lower, the neon current falls, and at 8v it is cut off. This experiment also shows the great amplification in the valve. Each electron on the grid controls 50m. electrons/sec, or 250×10^6 electrons on the grid control 1.3×10^{16} electrons/sec, or 0.002 amp. A somewhat similar, but slightly more complex, set-up can be used for the determination of ionization potentials. A triode valve has its filament heated by a current, the positive of the source being connected to the grid (via a voltmeter) and the plate (via a galvanometer), and to another battery circuit with variable resistance supplying the grid potential. At low grid voltages only electrons carry the current from the grid to the plate, as registered by the galvanometer. As the grid voltage increases, as shown in the voltmeter, the current to the plate increases to a critical point, then suddenly, because of the prolific ionization of the gas in the valve. The critical voltage is the ionization potential of the gas. Further current increases occur as the voltage is increased, and these indicate second, third ionization potentials, etc.



Circuit for showing the principles of ionization potentials



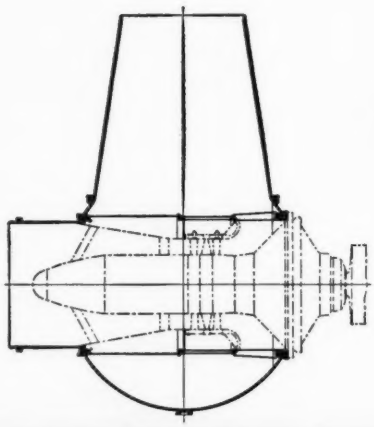
Circuit for determining ionization potentials

No. 32 An ingenious electroscope

Physical Science Study Committee, Education Services, Inc., U.S.A.

A 5 in. diameter coffee- or paint-tin has a ½ in. hole drilled in its side, and through this is passed a 1½ in. × 8/32 in. round-headed screw. Mounted on this, on the outside of the tin, are the following, in this order: a 1 in. diameter polythene insulator, a ⅝ in. metal washer, a small nut, an 18-gauge galvanized iron sheet (3 in. × 3 in.) with corners and edges smooth, and finally another small nut. Inside the tin, the same screw carries another 1 in. polythene washer and the armature support. The latter is made from 0.025 in. aluminium or brass stock, 3⅝ in. long, bent downwards to form a slightly divergent inverted V with legs 2 in. long then upwards again on each side for

New thinking for Trawsfynydd

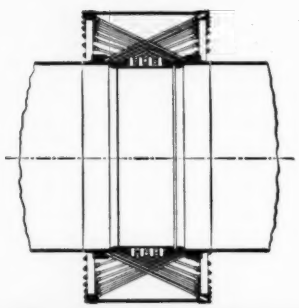


CO_2 CIRCULATORS

As every engineer knows, the thickness of plate required to contain a given pressure is halved if the vessel is spherical instead of cylindrical. It is odd—but nevertheless true—that it was not until our own engineers were confronted with the design of the CO_2 circulatory system for Trawsfynydd that the elementary principle was put into practice on large pressure pipework.
Besides halving the plate thickness spherical construction has other advantages. All welds are circular, can be prepared by machinery and are simple to X-ray.

CORNER BENDS

The same advantages follow when the same principle is applied to corner bends. In addition, the stiffeners required on cylindrical bends are eliminated. Internal tubes—not subject to pressure—provide a smooth gas flow.



EXPANSION JOINTS

It is standard practice to take up the expansion of large diameter pipework by flexing at what are essentially hinged joints. These of course have to provide restraint against axial forces—over 1,000,000 lb. in the Trawsfynydd ducting. The usual solutions, an internal metal tongue or a hinged joint are heavy, cumbersome and, moreover, flexible in one direction only. The hinge we have devised is flexible in *all* directions, by elastic straining of the high-tensile steel, restraining rods. The circumferential pressure is taken by a metal bellows, faired internally by a floating sleeve.

These ideas are not our only contribution to Trawsfynydd. As well as the complete CO_2 circulation system, we are building the whole of the generating plant, comprising steam turbo-alternators, condensing plant and feed heating systems.

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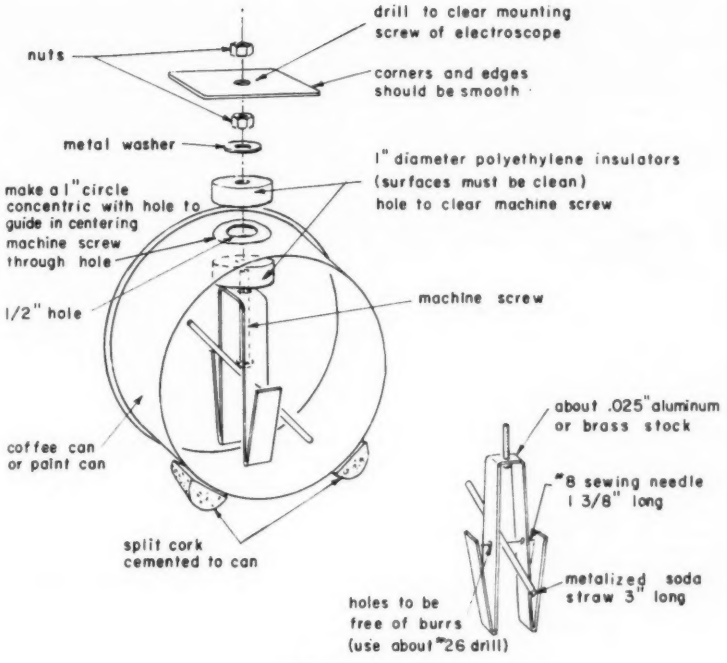

drill to clear mounting screw of electroscope
nuts
corners and edges should be smooth
metal washer
1" diameter polyethylene insulators (surfaces must be clean)
hole to clear machine screw
make a 1" circle concentric with hole to guide in centering machine screw through hole
1/2" hole
machine screw
about .025" aluminum or brass stock
coffee can or paint can
#8 sewing needle 1 3/8" long
split cork cemented to can
metalized soda straw 3" long
holes to be free of burrs (use about #26 drill)

Coffee tin electroscope

1 in. In the middle of each 2 in. leg a burr-free hole is drilled (No. 26 drill). This pair of holes carries a needle $1\frac{3}{8}$ in. long and of No. 8 gauge. This needle is the armature axle and carries a drinking straw cut down to $3\frac{1}{8}$ in. and pierced to balance accurately on the needle. The balanced needle and straw are mounted in the electroscope by spreading the supports to allow the needle to be inserted in its bearings. The base mount for the electroscope consists of a split cork cemented to the tin. The sensitivity is such that a 10° deflection results from a 300-400v potential difference. Lower voltages are insufficient to overcome the friction between the needle and its bearings.

No. 33 A Simple microbalance

Physical Science Study Committee and Macalaster Bicknell Co., U.S.A.

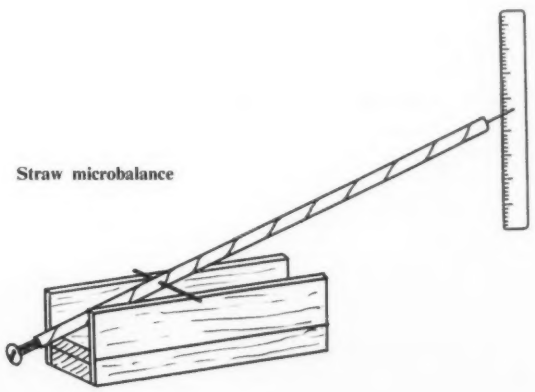
A drinking straw is weighted with a machine-screw ($\frac{1}{2}$ in. long) set into one end, and balanced upon a needle thrust through the straw to serve as an axle near the screw. The needle rests upon a support made as follows: two microscope slides are spaced $\frac{1}{2}$ in. apart by a wooden block 3 in. × $\frac{1}{4}$ in. × $\frac{1}{2}$ in., bound around with an elastic band. The microscope slides are held vertically with their long edges horizontal and their edges provide a hard smooth surface as bearings for the needle. The screw is adjusted so that the straw rests at some convenient angle to the horizontal. At the outermost edge the straw is cut away to leave a small bucket in which small masses may be weighed. These masses deflect the end of the straw downward by amounts which are read on a vertical scale. The balance is calibrated against known weights, and should be set in a special case to protect it from draughts.

No. 34 Magnetic susceptibility

Juan A. McMillan, U.S.A.

It is possible for students to determine the paramagnetic susceptibilities of substances using only a small electromagnetic (about 7,000 gauss field) and a Westphal balance. For a cylindrical sample, with axis normal to the field, of cross-section A, length L, the bottom end being in the maximum field at the middle of the pole pieces, and L being large compared with the diameter of the sample tube, and ignoring the small value of $k_o = 0.03 \times 10^{-6}$ emu/cc at NTP in the case of air, it can be shown that the force acting on the element of volume is given by the equation $f = (A/2)KH^2$, where H is the field strength and K the magnetic susceptibility. Introducing specific susceptibility $\psi = K/d$, where d is the apparent density, we get $f = (MH^2/2L)\psi$ where M is the mass of the sample. It is assumed that the powder specimen is uniformly distributed in a flat-ended cylinder of constant cross-section. The value of f is found by weighing the sample with and without the field. The difference m, which is positive for paramagnetics and negative for diamagnetics, can be inserted into the equation $\psi = 2Lmg/MH^2$. The use of known paramagnetic substances such as pure ferrous ammonium sulphate, with a ψ value of 32.6×10^{-6} emu/g at 17°C., H may be determined. It can also be shown (that $\psi = (mM_o/m_oM)\psi_o$ where ψ is the susceptibility of an unknown sample, of mass M.

The electromagnet, with flat pole pieces 30-35 mm diameter and 10 mm



Straw microbalance

apart, gives a field up to about 7,000 gauss. The Westphal balance is of the type used for liquids of specific gravity up to 2.0, with a plummet displacing 5 ml of water and sensitivity of about 10^{-4} g/cc. The sample tube, taking the place of the plummet, is a Pyrex tube 10-12 cm long, 6 mm i.d., with a flat bottom end. The sample, either a powder or a liquid, reaches to a level about two pole piece diameters. The tube is hung by means of cork and aluminium wire. The flat end of the tube is placed between the pole pieces. Both *M* and *m* are measured in terms of rider scales, so that unit rider weight and plummet displacements are not required. The diamagnetism of the reservoir necessitates a correction which is previously determined by weighing the reservoir with and without the field.

No. 35 Separation of radium-D, -E, and -F.

Edgar A. Dickey, U.S.A.

The chromatographic separation of Radium-D, -E, and -F is a fairly simple exercise for students. A gold capsule of spent radon is dissolved in 0.4 ml of *aqua regia*, and sufficient of the solution to give a count rate of about 5,000 c.p.m. is spotted on to a No. 1 Whatman filter paper, 18 cm diameter, about 15 mm from the centre. A similar spot is placed at another point, in combination with small amounts of lead and bismuth nitrates. The paper, air-dried, is ready for the irrigation apparatus. The latter consists of two Petri dishes, 15 mm × 50 mm and 22 mm × 150 mm respectively, the smaller inside the larger. The inner dish is half filled with butanol saturated with N aqueous HCl. In this the paper is left for about two hours, after which it is exposed to moist ammonia and then to moist hydrogen sulphide. On the carrier-bearing chromatogram are seen two brown spots, one of lead near the starting-point, the other of bismuth between the starting-point and the yellow spot of gold. The carrier-free chromatogram shows no such spots, because the concentrations are too small. The chromatograms are cut up and the papers counted under a thin-window GM counter over a period of two weeks. The count of the RaF(Po) decreases hardly at all, and this nuclide is found between the RaE and the gold. The RaE(Bi) count falls rapidly, and this nuclide is found about halfway along the chromatogram. The RaD count grows, and this element (lead) is near the starting-point.

No. 36 Mounting liquids for counting

Nuclear Chicago Corporation, U.S.A.

Small samples of liquid of high surface tension will give rise to geometry and self-absorption errors when mounted on flat planchets. For meltable samples a thick planchet with a vertical annular groove or moat at the outer edge is found suitable. Precoating of the periphery with silicone grease can also be used. The Nuclear Chicago Corporation markets a special copper planchet with concentric raised rings on the floor. Liquid samples added to the centre of the pan will fill the centre circle. If more is added, the liquid overflows to the next ring, and so on. A 1 ml sample will fill all the depressions to equal thicknesses. Use of this planchet greatly reduces the effect of capillary concentration in the corners. A disc of lens tissue, of thickness about 1 mg/sq.cm, will absorb very little radiation and can be used to soak up a liquid sample. Gelling agents such as aluminium stearate may be used in liquid sample counting, only a small concentration being required, so that absorption presents little difficulty.

No. 37 Counting on animal tissues

Nuclear Chicago Corporation, U.S.A.

Animal tissues and organs are not very easily examined for radioactivity. Several workers have found formamide valuable in this respect. An entire animal organ or body can be homogenized with a little water in a special machine, and then mixed with an equal volume of formamide. There results a clear colloidal solution which can be counted directly in a beaker, liquid counter, or planchet. The homogenizing process can be eliminated as follows: the tissue is cut off and dried at 80°, covered with formamide and heated at 105° for 30 minutes, then at 210° for an hour, with frequent stirring and the addition of more formamide to make up for evaporation. The solution, diluted with alcohol, can be placed on lens tissue discs resting on silicone-greased planchets. After drying under the infra-red lamp for 12 hours, the planchet is ready for counting.

No. 38 Nuclear Scientists

John Graely, U.K.

The value of charts in the teaching of atomic science is not to be underrated. The CEGB has prepared a series of 21 wall charts, each 20 cm × 30 cm, dealing with the work of individual scientists. Of particular interest in atomic science are those on Faraday (electromagnetic induction), Fleming (right hand rule), J. J. Thomson (discovery of the electron), Sir William Crookes (discharge of electricity in gases), Roentgen (X-rays), Becquerel and the Curies (radioactivity), Rutherford (structure of the atom, and alpha, beta and gamma rays), Aston (isotopes). These charts cost 2*s.* 6*d.* each, or £2 for a set of 21, postage included.

No. 39 Half-life of I-128

Charles A. Brown and E. G. Ruchow, U.S.A.

Iodine-128 has a life-time of only 25 minutes, making it excellent for the study of decay during a student's day, but not a nuclide which can be stored in the school premises after purchase. It must be prepared the day before use, by the neutron bombardment of I127.

A sealed capsule containing 5 mg of radium and 50 mg of beryllium is used as the source. This is placed in a spherical 1,000 ml flask containing ethyl iodide and a small amount of free iodine. The source is conveniently handled on a long rod, and held in a long glass tube of soft glass or quartz, with the lower end closed. Some I128 is produced, the recoil causing rupture of the C-I bonds, so that most of the active I is in the free state. After being left overnight, the assembly is dismantled and the iodine extracted by means of 5 ml of 10 per cent. NaOH, then precipitated as AgI. This

precipitate is collected for counting. A sample is mounted on a small paper disc on a wooden block, retained by Scotch tape and then placed in front of the GM tube. From the plot of time against count rate the half-life of the I128 is determined.

No. 40 Diffusion through a membrane

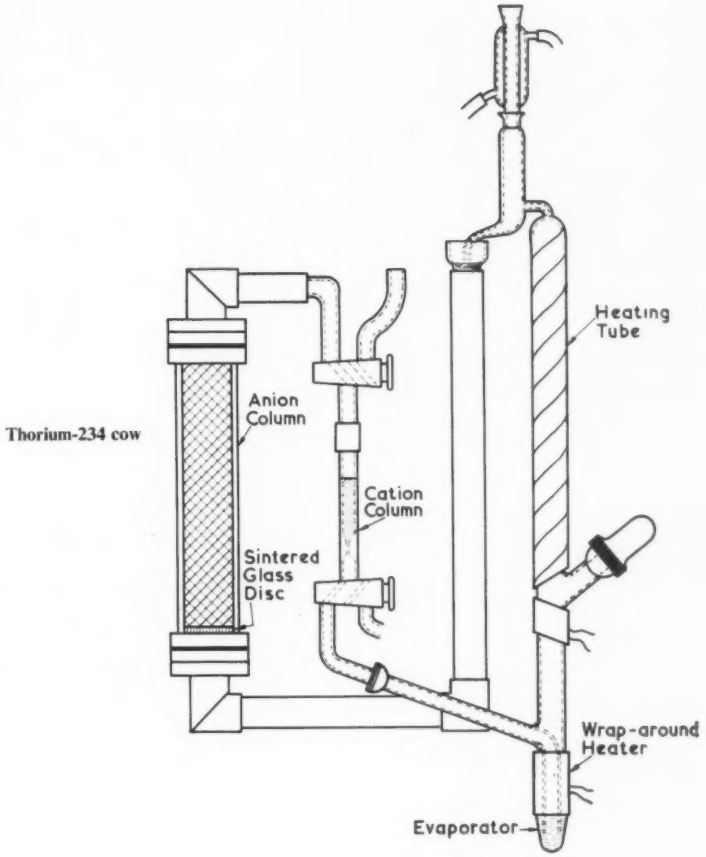
Joe W. Tyson, U.S.A.

A 500 ml beaker is divided into two equal compartments by cementing across the inside a sheet of Cellophane, using a waterproof glue. Into one compartment (*A*), 145 ml of distilled water is introduced, and 150 ml into the other side. A 50 microcurie sample of Cr51 in the form of sodium chromate, dissolved in 5 ml of water, is added to compartment *A*. After 30 minutes, 1.0 ml of liquid is removed from each compartment and transferred to planchets, evaporated and counted. By repeating the counting on samples taken at 30-minute intervals a good idea of the rate of diffusion is obtained, and a plot should be made of count rate against time for both compartments.

No. 41 Surface contamination and decontamination

Institut National des Sciences et Techniques Nucleaires, France.

Several surfaces are contaminated with small amounts of P32, suitable materials being wood, aluminium, plastics, and steel. By means of a portable beta detector the contaminated area is delineated and marked around with a grease pencil, the average count rate being recorded. By means of small plugs of wooden wool, held in forceps, the decontamination agents are rubbed into the surfaces. For plastics the decontamination materials should be water and Teepol, while for the other materials 10 per cent. phosphoric acid, and soap can be used. After rubbing, the cotton wool plugs should be disposed of in a special receptacle. Count rates are again determined. Efficiencies are compared for the various decontamination agents on the various surfaces. It can be seen which surface is most easily cleaned. One may also try the effect of phosphoric acid followed by Teepol or soap on steel surfaces.



No. 42 Another Thorium-234 Cow

D. J. Carswell and J. J. Lawrence, Australia.

In an earlier issue mention was made of a small "cow" for supplying Th234 on demand. The same workers have since made a larger version of this device. The anion bed volume is 600 ml and the bed is laid in a 1 ft length of 2 in. diameter Pyrex tube (industrial) with a sintered glass disc at the bottom. Black polythene $\frac{1}{2}$ in. i.d. tubing and fittings are used in the active circuit. Upward elution allows the use of a completely closed circuit below the level of the top of the anion bed, thus minimizing the risk of a leak in the active circuit and the possibility of the bed running dry. Active flow is controlled by the flow of inactive acid to the base of the column, and circulation of acid during milking is ensured by distillation. This means no moving parts, simple flow control, continuous acid purification, and absence from flooding, as circulation ceases if the acid level in the evaporator falls below the heating element. The anion column is filled with 16-50 mesh De-Acidite FF, cycled from Cl' form to OH' form and back again to Cl'. Now 60 g of uranium is adsorbed on the bed from constant boiling HCl. A small Zeo-Karb 225 column of 5 ml volume in the overflow circuit concentrates the Th234. Flow rate is 3-4 ml/min, so that $2\frac{1}{2}$-3 anion column volumes of acid flow in one eight-hour working day. As carrier, 1 mg of Th232 is added, in HCl solution. The evaporator and condenser waters are switched on for one day. The following day the Th tracer is eluted from the cation column with oxalic acid. Oxalate is then destroyed by nitric acid and hydrogen peroxide, leaving the thorium in nitric acid suitable for most radiochemical operations.

The Nuclear Power Group are at present concerned with the construction of three nuclear power stations in this country; these are at Dungeness, Berkeley and Bradwell. This article gives a brief account of progress to date on the stations being built by this Group.

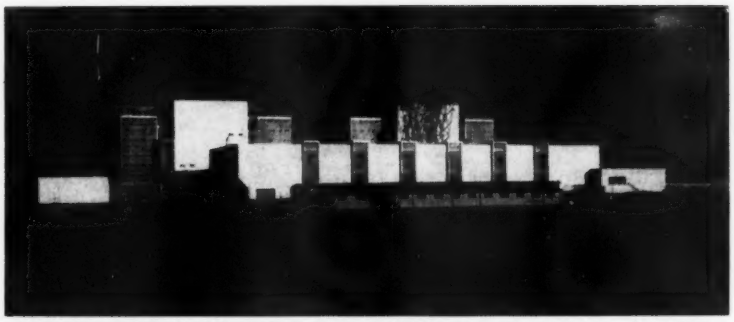
POWER STATION REVIEW

Berkeley

Bradwell

Dungeness

TWO of the nuclear power stations at present under construction by The Nuclear Power Group are nearing completion while the other is still at the excavation stage. Berkeley and Bradwell have long been progressing neck and neck; now, however, Berkeley seems to be slightly in the lead. Work on both stations started in January, 1957, but is considerably behind schedule due to modifications which became necessary after the Windscale incident in 1957. The baby of the family is Dungeness, where work started in August of last year. Although the baby at present, Dungeness is destined to be the largest and cheapest producer of the three with a capacity of 550 MW, while that of Berkeley will be 275 MW and of Bradwell 300 MW. The cost in pounds/kW for the three stations will be £110, £160 and £159 respectively.



General view of Bradwell from the banks of the Blackwater. No. 1 reactor and the CW pumphouse are on the right

Bradwell

At Bradwell, practically all the civil engineering work has been completed. Graphite laying in No. 1 reactor is finished and work on the control rod installation is well advanced. The two charge/discharge machines have been built and all six blowers tested. Fuel for this reactor should be loaded towards the middle of the year.

Graphite laying for No. 2 reactor at Bradwell is well advanced, and the pile cap area is being fitted with the various items of equipment. The six boilers have been tubed and the gas circulators are approaching completion, the first charge/discharge machine for this reactor is at present under construction.

Water tests on the cooling pond have been almost completed and in the turbine house five of the six 52 MW sets are finished, work is continuing on the last one. The diesel house, water treatment room, battery room, etc., are all completed and the control room is at an advanced stage.

The finishing touches are being put to the last of the three 15 MW auxiliary turbo-alternators in the auxiliary turbine house. These alternators will supply electricity to the variable frequency motors for the blowers. Testing of the CW side is in progress.

Interior view of main turbine hall at Bradwell. Five of the six 52 MW main turbo-generators can be seen

Bradwell is now in the commissioning stage and No. 1 reactor is expected to go critical later this year.

Berkeley

The emphasis at Berkeley has moved from the civil and mechanical work which is virtually complete, to the electrical installations, cabling, and commissioning of No. 1 reactor.

The commissioning programme began at the end of 1960 and should be completed during April. The reactor circuit system, including pressure vessel, boiler and ducting has been pressure tested and the CO_2 gas blowers have been run at speed.

Gas flow speeds through each of the 3,275 channels in the graphite core are being checked with air. The gas flow is checked by means of a "gag" placed at the bottom of the channel. The correct gas flow must be obtained through each of the channels before the insertion of the fuel. The first fuel should be inserted sometime in April and the reactor should be operating at full power by the end of the year.

No. 1 reactor is approximately six months in front of No. 2 so the power station will be fully operational by the middle of 1962. The cooling water system for No. 2 reactor has been completed whilst the four 83 MW turbo-alternators in the turbine hall are almost finished. Full electrical tests are proceeding on the control room which is virtually complete.

Berkeley viewed from the CEGB research laboratory. In the foreground is No. 1 reactor which is at present undergoing commissioning tests. Charging of this reactor should begin in April, 1961. Charging of No. 2 reactor should begin in October

View at Dungeness from the top of the new concrete batching plant; on the left can be seen excavations for the reactors, centre for the steam pipe tunnels linking the reactors to the turbine house and right those for the turbine house itself. Spoil from the excavations will be used in the batching plant to make concrete for subsequent building work

Checking the readings of anemometers from the 128 fuel channels immediately after gas flow test at Berkeley

Dungeness

At Dungeness work is still at a very early stage. One of the first tasks facing the civil engineers, Sir Robert McAlpine & Sons, Ltd., was the need to surround the whole area of the reactor and turbine house with a girdle of interlocking steel piles. The original contract specified that the existing water table which is about 10 ft below ground level must be maintained outside the area of the site to avoid interference with the level in the wells which are the source of Folkestone's water supply. After the steel girdle had been driven down to a depth of 45 ft, water could be pumped from the centre without fear of reducing the surrounding water table. So far some 38 wells have been sunk in this area and are at present removing about 100,000 gal of water/hr.

About 800 men are now employed on the site, mostly on civil engineering work. The deepest level has been reached in the reactor excavations and concrete is being poured in the main foundations. Excavations are continuing for the turbine house and other main structures. The site on which this station is being built is covered with a formation of shingle. As this shingle is removed it is piled up on the west side of the site and this will eventually be used as raw material for making concrete. A large batching plant has been built on site for concrete production.

Close-up of excavations for No. 1 reactor at Dungeness. Excavation work at this power station is being carried out by Sir Robert McAlpine & Sons

Work is in hand on the reactor pressure vessel fabrication area. Temporary workshops have been built for the fabrication of boilers by John Thompson. Measures are being taken for the erection of a jib crane which will be used to build a 400-ton travelling Goliath crane for use in the erection of boilers and for lifting sections of the pressure vessel.

Calculation of parametric information for fast reactors

by R. E. Reid

WIDE use has been made of transport theory calculations for the nuclear analysis of small fast reactors because of the limitations of diffusion theory calculations for this type of reactor. One of the main problems in the use of transport theory calculations is the large computer time per problem. This factor makes the accomplishment of nuclear parametric studies on conceptual and preliminary fast reactor designs a prohibitively costly operation for most installations. To surmount this problem a method based on first-order perturbation theory, which accurately estimates the effect of large physical changes on the nuclear characteristics of fast reactors, has been developed from B. H. Duane's variational optimum formulation of transport theory[1].

The logic for developing a first-order perturbation theory method is based on the nuclear characteristics of fast reactors. These reactors are primarily composed of heavy elements which have small scattering cross-sections in the high energy range and a small degradation of energy per scattering collision. These poor moderation qualities preclude any radical changes in the flux spectrum even if material concentrations change quite radically. If an effectively infinite reflector is wrapped around the reactor, this will also preclude any radical changes in the flux spectrum of the core and reflector for large changes in the reactor size. Under the above described conditions of small flux spectrum variation, first-order perturbation theory is applicable.

The use of first-order perturbation theory for performing parametric calculations on fast reactors with infinite reflectors was first suggested

This paper was presented to the American Nuclear Society on December 13th, 1960.

by S. B. Shikhov[2]. He developed equations for this purpose at the diffusion theory level of approximation and demonstrated good agreement with diffusion calculations in the prediction of the critical mass of spherical fast reactors over a broad range of core sizes covering a variation of about 2:1 in radius.

Advantages

The presently proposed method offers advantages over Shikhov's method both in theoretical rigour and calculational convenience. Duane's variational optimum formulation of transport theory, as embodied in GE-ANPD Programme S-VII, is based on calculating the flux and adjoint simultaneously from the flux and adjoint transport equations respectively and solving for the eigenvalue of interest in an integrated action principle which essentially eliminates first-order errors in the solution. The first-order perturbation theory equation used for the parametric calculation is derived from the integrated-action principle and is at the transport theory level of approximation rather than the diffusion level. The perturbation theory integrals for this equation are calculated in a sub-routine of Programme S-VII for each material in the reactor. This feature adds a new dimension of convenience in the use of first-order perturbation theory calculations by eliminating the time-consuming task of calculating flux and adjoint separately and combining them in the perturbation integrals by hand or another computer programme.

Theory

The following sections outline the theory behind the perturbation theory method and describe comparisons of the perturbation theory predictions with variational optimum transport theory calculations. The ZPR-III spherical assembly 6F[3] and a spherical reactor in the size range that might be considered for a SNAP reactor are used as the reactor models for these calculations.

B. H. Duane has indicated that a formulation of first-order perturbation theory at the transport theory level of approximation is obtainable from the integrated action principle of his variational optimum formulation of transport theory[4]. This formulation of perturbation theory can be stated as follows:—

$$\frac{1}{2}\int[\phi^*(r,p)\delta\nabla\,.\,\Omega\phi(r,p)-\phi(r,p)\nabla\delta\,.\,\Omega\phi^*(r,p)]dV(r,p)$$

$$+\sum_{m=1}^{M}\int\phi(r,p)[\delta\Sigma_{Am}(H,r,p)]\phi^*(r,p)dV(r,p)$$

$$=\frac{\pi}{4}\sum_{m=1}^{M}\int\phi(r,p')[\delta\nu\Sigma_{Fm}(H,r,p'/p]\phi^*(r,p)dV(r,p',p)$$

$$+\frac{\pi}{2}\sum_{m=1}^{M}\int\phi(r,p')[\delta\Sigma_{Sm}(H,r,p'/p,\Omega'\,.\,\Omega)]\phi^*(r,p)dV(r,p',p) \quad . \quad . \quad (1)$$

where $\phi(r,p)$ and $\phi^*(r,p)$ are the flux and adjoint in position r, momentum p and volume element $dV(r,p)$; Ω is the unit vector p/p; Σ_{Am}, Σ_{Fm} and Σ_{Sm} are the macroscopic collision, fission and scattering-transfer cross-sections of material m; and H represents any definable eigenvalue.

Changes in the size of the reactor only affect the gradient operator of the first term of equation (1) since it is the only term that is dependent on the dimensions of the system. If l is any dimension of a reactor and all dimensions of the core and all dimensions of the reflector change by the same factor so that l becomes l', then:—

$$\delta\nabla=\nabla\left(1-\frac{l}{l'}\right) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If N_m is the atomic density of a material m and N_m' is the perturbed value then:

$$\delta\Sigma_{Am}(H,r,p)=\Sigma_{Am}(H,r,p)\left(1-\frac{N_m'}{N_m}\right) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$\delta\Sigma_{Fm}(H,r,p'/p)=\Sigma_{Fm}(H,r,p'/p)\left(1-\frac{N_m'}{N_m}\right) \quad . \quad . \quad . \quad . \quad (4)$$

$$\delta\Sigma_{Sm}(H,r,p'/p)=\Sigma_{Sm}(H,r,p'/p)\left(1-\frac{N_m'}{N_m}\right) \quad . \quad . \quad . \quad . \quad (5)$$

Using the following symbolism:

$$L_m=\frac{1}{2}\int[\phi^*(r,p)\nabla\,.\,\Omega\phi(r,p)-\phi(r,p)\nabla\,.\,\Omega\phi^*(r,p)]dV(r,p) \quad . \quad (6)$$

$$C_m=\int\phi(r,p)\Sigma_{Am}(H,r,p)\phi^*(r,p)dV(r,p) \quad . \quad . \quad . \quad . \quad (7)$$

$$FP_m=\frac{\pi}{4}\int\phi(r,p')\nu\Sigma_{Fm}(H,r,p'/p)\phi^*(r,p)dV(r,p',p) \quad . \quad . \quad . \quad (8)$$

$$S_m=\frac{\pi}{2}\int\phi(r,p')\Sigma_{Sm}(H,r,p'/p,\Omega'\,.\,\Omega)\phi^*(r,p)dV(r,p',p) \quad . \quad . \quad (9)$$

and selecting the loading eigenvalue of U-235 in the core of a reactor as H, equation (1) can be written:

$$L\left(\frac{l-l'}{l'}\right)+\sum_{m=2}^{M}\left(C_m-FP_m-S_m\right)\left(\frac{N_m-N_m'}{N_m}\right)$$

$$+\left(C_1-FP_1-S_1\right)\left(\frac{1}{k_1}-\frac{N_1'}{N_1k_1'}\right)=0 \quad . \quad . \quad . \quad . \quad (10)$$

This equation, of course, can be written in terms of any eigenvalue, but for purposes of this study the core fuel loading was the most convenient.

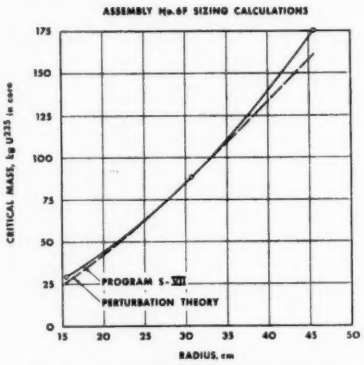


Fig. 1.—Comparison of transport theory calculations with first-order perturbation theory calculations on ZPR-III assembly No. 6F

The results of nuclear parametric studies are mainly used to size reactors, *i.e.*, find reactors which have dimensions and compositions which will meet the nuclear criteria desired within the limits dictated by thermodynamic and mechanical considerations. To demonstrate the validity of the perturbation theory method to generate accurate estimates for sizing purposes two studies were performed. First, the dimensions of the ZPR-III assembly 6F and the SNAP type reactors were varied over a wide range of sizes and the critical mass at each size was calculated using equation (10). The results were then compared with Programme S-VII calculations. Secondly, perturbation theory calculations were made to determine the changes in critical mass caused by changes in the composition of assembly 6F and the results compared with Programme S-VII calculations.

The specifications for assembly 6F and the SNAP type reactor are given in Table 1. For all practical purposes the reflector of assembly 6F is infinite. The reflector on the SNAP type reactor is not infinite, however, so more error can be expected in sizing calculations involving this reactor.

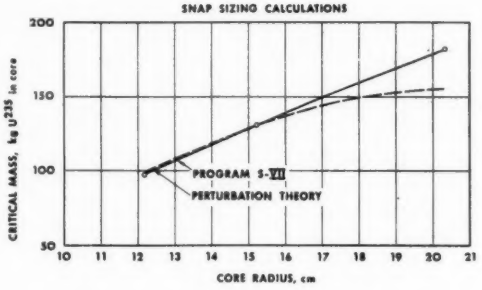


Fig. 2.—Comparison of transport theory calculations with first-order perturbation theory calculations on SNAP type reactor

In Fig. 1 the perturbation theory predictions of critical mass for various core sizes of assembly 6F are compared with Programme S-VII calculations. The perturbation theory calculations were made with the data generated by the Programme S-VII calculation at a core size of 30.78 cm. It can be seen that the perturbation calculations are quite accurate over a range of radii of better than 2:1.

The same comparison as shown in Fig. 1 is drawn in Fig. 2 for the SNAP type reactor. It can be seen that the perturbation calculations in this study were not quite as accurate as in the previous study especially when sizing toward larger dimensions. The thinner reflector may have been the cause of this increased error.

A second study was carried out in which perturbation theory predictions were made of the change in critical mass which would be caused by replacing the aluminium in the core of the original assembly 6F with molybdenum. Calculations were made using the perturbation theory data from both the original assembly 6F and assembly 6F with a diameter of 30.78 cm. The calculation from the larger radius, of course, involved a change in size as well as a change in composition.

Fig. 3 gives the results. It can be seen that the accuracy is good in both cases. It should be noted that molybdenum was not included in the original reactor. However, provision is made in Programme S-VII for calculating the perturbation integrals of any material for which cross-sections are supplied as input

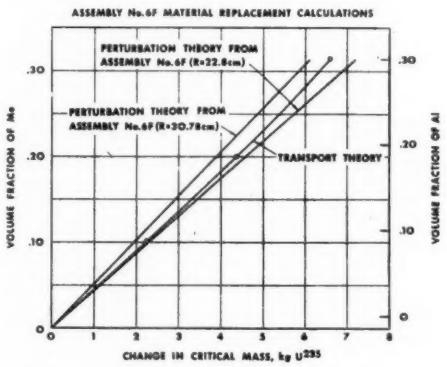

ASSEMBLY No. 6F MATERIAL REPLACEMENT CALCULATIONS
PERTURBATION THEORY FROM ASSEMBLY No. 6F (R=22.8cm)
PERTURBATION THEORY FROM ASSEMBLY No. 6F (R=30.78cm)
TRANSPORT THEORY
VOLUME FRACTION OF Mo
VOLUME FRACTION OF Al
CHANGE IN CRITICAL MASS, kg U235

Fig. 3.—Comparison of transport theory for prediction of change in critical mass caused by substitution of Mo for Al in ZPR-III assembly No. 6F

(*Continued on page* 164)

Table 1.—Reactor Specifications

Reactor	Core diameter	Reflector thickness	Core volume fractions				Reflector volume fractions			
			U^{235}	U^{238}	Al	SS	U^{235}	U^{238}	Al	SS
6F	45.6 cm	30.0 cm	0.128	0.159	0.314	0.123	0.0019	0.833	0.0227	0.0731
SNAP	30.48 cm	25.4 cm	0.096			0.160			0.0500	0.950

Beryllium has been known since the end of the eighteenth century and has for some time been used in copper alloys, but it is the development of atomic reactors that has made the preparation and working of the metal an important industrial process. The very low neutron cross-section of the metal makes it valuable as a canning material for the fuel rods in gas-cooled reactors. The processing of the metal presents many unusual features, resulting from both the inherent physical properties of the metal and its high toxicity.

BERYLLIUM

by **M. K. McQuillan**
and
T. W. Farthing

BERYL, the mineral which gives beryllium its name and which is still the only commercial source of the metal, has been known for thousands of years, both as a semi-precious gemstone and, in its green single-crystal form, as emerald. The history of the metal itself, however, is much shorter. It was isolated in 1798 by Vauquelin, but its debut as an industrial material occurred only about 30 years ago, when it was observed that small additions of beryllium to copper could give the latter the strength and elasticity which pure copper notoriously lacks but without destroying the high thermal and electrical conductivity upon which so many of the uses of copper depend.

Use in Reactors

Copper-beryllium alloys still account for about three-quarters of all beryllium extracted from its ores, but in the last 15 years or so the pure metal has become of interest, because of its exceptional combination of properties, as a material for use in nuclear reactors. Without this development it is very probable that pure beryllium would still be little more than a metallurgical curiosity, although, as we shall see later, it has other possible applications.

Low Absorption

From the point of view of a nuclear engineer, the most important single property of beryllium metal is its very low absorption of thermal neutrons—the lowest of any structural metal. Neutrons are the means by which nuclear reactions are propagated in reactors, and reactor efficiency thus depends on keeping adventitious neutron absorption and losses to a minimum. Neutron-absorption characteristics are therefore among the principal factors determining choice of reactor materials, and hence beryllium is naturally favoured in this respect. It has, moreover, a very low atomic weight, which fits it for use as the moderator, the material surrounding the fuel and serving to slow down the neutrons produced in the fission process so that they can more efficiently interact with further uranium nuclei.

General Behaviour

Although the essential characteristic of beryllium, from the nuclear engineering point of view, is its low neutron-absorption it is also of interest to consider its general behaviour under neutron bombardment, as this will largely govern its behaviour in a reactor. When beryllium is bombarded with fast neutrons (about 2 MeV) the main nuclear reactions occurring are those producing helium and tritium (^{3}H):

1. (n, 2n)

$$^9\text{Be} + \text{n} \longrightarrow {}^8\text{Be} + 2\text{n} \quad (200\ \text{millibarns}^*)$$

$$^8\text{Be} \longrightarrow 2\,{}^4\text{He}$$

2. (n, α)

$$^9\text{Be} + \text{n} \longrightarrow {}^6\text{He} + {}^1\text{He} \quad (50\ \text{millibarns})$$

$$^6\text{He} \xrightarrow{\beta} {}^6\text{Li}$$

$$^6\text{Li} + \text{n(thermal)} \longrightarrow {}^1\text{He} + {}^3\text{H} \quad (950\ \text{barns})$$

$$^3\text{H} \xrightarrow{\beta} {}^3\text{He}$$

Irradiation experiments suggest that, at temperatures below 600°C., gases produced during neutron irradiation will not have any serious effect on the properties of beryllium.

Discovery of the promising nuclear properties of beryllium led American workers to undertake, in the period 1945-50, an intensive study of its technology, on the results of which a considerable part of present-day industrial practice has been based.

*The barn (10^{-24} cm^2) is the unit of neutron cross section.

Since then there has been some slackening of American interest in beryllium because the general trend of reactor design for power production in America has been towards a pressurized-water reactor operating at about 300°C., for which beryllium would have inadequate corrosion resistance. Now, however, a developing interest in new types of reactor—such as the so-called packaged reactors, which are intended to provide a flexible and transportable power source, and high-temperature forms of the gas-cooled reactor—is again bringing beryllium to the forefront of the American nuclear-energy programme.

Use in AGR?

In Britain, reactor design has taken a different course. The reactors favoured here for power production are graphite-moderated and gas-cooled, as typified by Calder Hall and its successors, and in such reactors beryllium can be expected to make an excellent sheathing (canning) material for the uranium fuel, as it is compatible with the graphite core into which the sheathed fuel is inserted. Interest in beryllium among British nuclear engineers has consequently been maintained, though the metal has not yet been used because so far operating temperatures have been such that the temperature at the surface of the fuel can has not exceeded 400-500°C., at which level more readily available materials, notably magnesium, can be used. At higher operating temperatures such as are proposed for a new type of experimental reactor, known as the Advanced Gas-cooled Reactor (AGR), the surface of the fuel can is expected to reach about 600°C., at which present canning materials will have insufficient strength and stability. They must therefore be replaced by material having greater high-temperature strength.

Higher operating temperatures will also involve a change in the nature of the fuel itself. When irradiated with neutrons, uranium swells and changes its shape. At the working temperature of Calder Hall and of the nuclear power stations now being built in Britain this is not a serious problem, but under the more exacting conditions of the AGR the swelling of the uranium would create much greater difficulties. For the AGR the fuel will, in fact, be uranuim oxide, which has considerably better dimensional stability under irradiation. The proposed change in fuel, however, brings with it new problems, because uranium oxide suffers from the disadvantage of poor thermal conductivity: in order to provide sufficient cooling, the diameter of the individual fuel rods has to be appreciably decreased, thus increasing the proportion of sheathing to fuel in the core. In the new design, therefore, sheathing-material of low neutron-absorption is more important than ever. It is fortunate that in beryllium, which from this point of view is the obvious material to use, we have also a material of reasonably high melting point (1,285°C. as compared with 650°C. for magnesium), which promises good high-temperature strength; thus two of the major problems of the AGR concerning constructional materials can be solved simultaneously. It has therefore been decided to use beryllium cans for the AGR, and in consequence industry is now for the first time dealing with the metal in quite large quantities. As we shall see, this is no easy task, for reasons connected with both metallurgy and with the health of the workers concerned.

Properties

Beryllium is a true metal, in that it has the electrical and thermal properties and the lustrous appearance by which metals are usually recognized. At the same time it has other characteristics which set it apart from the general run of metals and put difficulties in the way of its industrial use.

One of the most important of these is its behaviour on deformation. The malleability which allows metals to be worked into complex shapes is a consequence of their simple crystal-structure together with the absence of direct and specific bonds between one atom and the next. Under an applied force it is possible for atoms in one plane of a metal crystal to move with respect to those in an adjacent parallel plane* without disrupting the crystal, the sum of a large number of such atomic-scale movements making up a microscopic shear. Naturally, different forces will be required to produce shear on different crystal planes. In normally malleable metals the shearing process occurs on one type of plane after another as the component of applied force, resolved in the appropriate direction of shear for each type of plane, exceeds the critical magnitude for the plane in question. The higher the degree of symmetry in the crystal lattice the greater the number of planes on which the shearing process (slip) can take place and the smaller the range of magnitude for the critical shear-stresses involved.

Beryllium has a crystal structure of the close-packed hexagonal type. Its axial ratio, however, is 1.568, which is too small for ideal close-packing; beryllium is not, therefore, among the metals having the highest degree of symmetry. Nevertheless, there is no *a priori* reason why a metal having such a crystal structure should not be fairly readily deformed by making use, for instance, of slip on the pyramidal {1011} planes, as in titanium, which has a closely similar crystal structure and which can be very ductile indeed. Normal commercial beryllium, however, does not in fact deform in this way. Slip can occur on the basal (0001) plane and on the prismatic {1010} planes, the slip directions being <1120>. Unfortunately at room temperature the critical resolved shear-stress for slip on the {1010} planes is high compared with the stress needed to bring about cleavage fracture on the (0001) plane, and consequently cracking tends to occur before very much {1010} slip takes place. In practice, therefore, room-temperature deformation is confined to slip on the (0001) plane, and forces applied in the majority of directions in the crystal will cause brittle fracture.

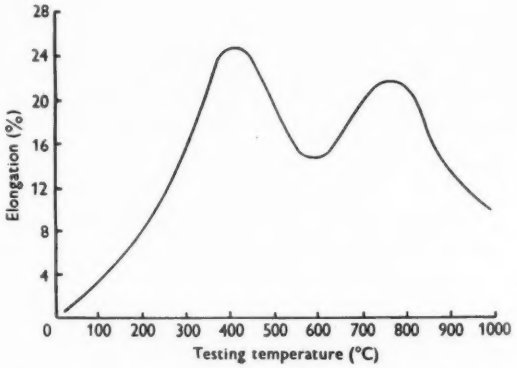


Fig. 1.—Effect of temperature on the ductility of polycrystalline beryllium as measured by elongation to fracture in short time tensile test

Ductility

This inconvenient behaviour on deformation means that the polycrystalline aggregate making up a normal piece of beryllium will not have sufficient ductility for engineering purposes unless special care is taken to ensure that the grain structure is such as to allow maximum advantage to be taken of the slip that can occur before fracture takes place. It is essentially a question of achieving a sufficiently small grain-size coupled with a suitable grain-orientation, and the technology of beryllium is considerably complicated by the requirements of grain-structure control.

Another characteristic of commercial beryllium that has considerably influenced the development of working procedures is the complex relationship between temperature and ductility, the form of which, as suggested by early work on beryllium[1] is illustrated in Fig. 1. A rather more detailed picture may be revealed by current investigations—indeed, it has already been shown by A. B. Brown, F. Morrow, and A. J. Martin[2] that suitably treated beryllium can have high ductility in the temperature region of about 600°C.,

*This process does not, of course, involve the movement of whole planes of atoms simultaneously—such a movement would require impractically large forces—but is accomplished by the propagation through the crystal of imperfections in the lattice known as " dislocations ".

where a minimum in the ductility/temperature curve is normally observed—but, at present, production practice is still governed very much by the need to work at a carefully controlled temperature in order that sufficient ductility can be reliably produced.

Lightness

Beryllium has a number of other chemical and physical properties—some advantageous, some the reverse—which set it apart from the common run of metals. It is, for example, exceptionally light, having a density of only 1.85 g/cu.cm, and it is certainly the lightest of potential structural materials. In beryllium, lightness is also coupled with quite high strength and—even more important—very great rigidity; its ultimate tensile stress ranges from 20 to 50 ton/sq.in. at room temperature, and its modulus of elasticity (44×10^6 lb/sq.in.) is far above that of most other metals. The thermal conductivity of beryllium at room temperature (0.385 cal cm/sq.cm/sec°C.) is exceeded only by those of gold, silver, copper and aluminium, and its specific heat (0.425 cal/g °C.) is also high.

Beryllium Oxide

Chemically, beryllium shows many similarities to aluminium. It is extremely reactive *per se*, but in air or oxidizing atmospheres at room temperature it forms a thin, adherent, impervious surface-film of inert oxide which can protect the metal against certain types of chemical attack, giving it a spurious nobility. The protective characteristics of beryllium oxide (beryllia) are also evident in the resistance to tarnishing or oxidation shown by some beryllium-containing alloys. Silver, for instance can be made appreciably more resistant to tarnishing by the addition of very small quantities of beryllium.

Beryllium dissolves rapidly in sulphuric and hydrochloric acids, but in nitric acid the rate of attack depends on acid concentration. Under some conditions the rate of attack by nitric acid falls to zero, the metal becoming passive. This is probably explained by the ease with which a protective coating of beryllia may be re-formed under oxidizing conditions. The corrosion of beryllium by neutral aqueous solutions is extremely variable, largely because of the important part played by very small quantities of impurities in the metal or the corroding medium, which cannot always be accurately controlled. For instance, the presence of a small amount of the ion of a more noble metal in the corrosive solution may give rise to pitting, as in the case of aluminium. As the quality of the metal available for research in the past has not been consistent, interpretation of the corrosion behaviour of beryllium is not always easy.

"Breakaway"

In the conditions foreseen for the AGR, that is, in carbon dioxide at 600°C., beryllium behaves satisfactorily as long as the gas is dry, but when water vapour is present the material is liable to suffer sudden marked increases in corrosion rate after a lapse of time. This phenomenon is known as "breakaway," which graphically describes the often catastrophic effects of the change in the corrosion rate.

Above about 700-800°C., beryllium begins to react at an appreciable rate with air. For hot working processes, therefore, some form of protection against oxidation must be provided, not only because it is difficult to work with a material which forms a heavy surface scale, but also because the dissemination of beryllium oxide in the atmosphere constitutes a severe health hazard. Molten beryllium is extremely reactive and will attack most materials with which it comes in contact; it can, however, be contained in crucibles made of beryllium oxide.

Beryllium Processing

Beryllium is extracted from beryl (beryllium aluminium silicate) by a process having four principal stages:

1. Separation of the beryllium content of the ore.
2. Conversion to beryllium hydroxide.
3. Production of a halide of beryllium.
4. Reduction of the halide to metal.

The separation stage involves treatment with flouride or sulphate, producing a water-soluble beryllium salt from which the hydroxide is precipitated with alkali. The choice of the halide into which the hydroxide is then converted depends on the reduction method to be used. For reduction with magnesium, the method commonly used in the United States, the material required is beryllium flouride, but for an alternative process, developed principally in France and involving electrolysis in a fused-salt bath, beryllium chloride is used. The two processes yield beryllium metal in different forms, magnesium reduction producing material described, from its appearance, as "pebble," and the electrolytic method giving dendrites or flakes.

Purity

Neither reduction process gives "raw metal" sufficiently pure for direct use; if processed without further purification the corrosion resistance of the product would be poor and very variable. It is necessary, therefore, to remove impurities—particularly residual volatile substances such as magnesium, sodium, and halides—in order to ensure a final product that has satisfactory corrosion-resistance and is uniform in its other properties. This is done by vacuum melting, usually in an induction furnace using a beryllia crucible; electric-arc melting has been used, but only on a much smaller scale.

Grain Structure

The grain structure of the cast material is such that its room-temperature ductility is close to zero, and the room-temperature mechanical properties obtained after processing it are not as good as those of material produced from fine-grained starting stock. To achieve optimum properties, therefore, it is necessary to convert the ingot to fine powder, and consolidate it once more by one of the several different techniques to produce fine-grained metal. Powdering is done first by turning the ingot to swarf and then grinding to 200 mesh. Ball mills are sometimes used, often with tungsten carbide balls to reduce iron contamination, but when contamination must be at a maximum the swarf is ground between beryllium plates in an attrition mill.

Methods available for consolidating the powder range from the old-established powder metallurgy technique of cold pressing, followed by sintering to the method known as

pressureless sintering. This consists of pouring loose powder into a suitable die and consolidating it, without applying pressure, by heating it in vacuum at a temperature very little below the melting point. More efficient consolidation is achieved, however, by compressing the powder at elevated temperatures, thus combining the compacting and sintering operations, and though this puts very severe stress on the compacting tools and can be very time-consuming it has become the most common procedure. The operation is done in vacuum at 1,000-1,100°C. under an applied pressure which may be anything from about 50 lb/sq.in. up to about 1 ton/sq.in. The actual pressure is determined by such practical factors as the type of die material available and production economics. Hot pressing was first applied to beryllium in the United States, as an alternative to casting for producing large slabs of metals required for reflectors in an early materials-testing reactor. The method has since been developed there to a stage at which pieces of metal several inches thick and about 10 sq.ft in area can be made on a regular production basis. Cylinders about 4 or 5 ft in diameter and the same in height, and other shapes weighing up to 2,000 lb, are also being successfully manufactured.

Working

Even in the fine-grained condition beryllium has insufficient ductility at room temperature (about 3-5 per cent. elongation) to make cold working practicable, but further fabrication can be carried out by extrusion, rolling, forging, and other normal working techniques at temperatures sufficiently high to bring the prismatic {1010} slip planes into operation. In practice, working temperatures range from 400°C. upwards. At 400°C. advantage can be taken of the first peak on the ductility/temperature curve; the maximum working temperature is usually 1,000-1,050°C.

During mechanical working the beryllium crystals tend to arrange themselves in such a way with respect to the direction of working that slip occurs easily in this direction. In normal wrought beryllium, which is most commonly produced by extrusion, ductilities of up to 30 per cent. can be expected in the longitudinal direction. Elongations as high as 50 per cent. in the rolling direction have been obtained in specially prepared sheet, but in directions other than the rolling direction much lower ductilities are exhibited. When there are two working directions, as for example in cross-rolling, high elongations can occur in both directions, but the ductility in the direction perpendicular to the plane of the sheet is again very low.

The Toxicity of Beryllium

One of the most important points to be taken into account in processing beryllium is that it is highly toxic. This manifests itself in two main forms—an acute irritation of the respiratory tract, including chemical pneumonia, and a chronic disease of the lungs, now known as beryllosis. Like many other metals, beryllium may also cause skin infections such as dermatitis and ulcers, particularly if it finds its way into an open wound, though compared with the effects on the lungs this is of less importance. Various views have been expressed on the relative toxicities of different beryllium compounds, but from the health point of view, all compounds must be regarded as suspect. Much still remains to be learned of berylliosis, but it is becoming clear that only relatively few people are susceptible to it: it appears to have aspects akin to those of an allergy. A very disconcerting feature of the disease is that its onset may be delayed until many years after the last time at which the victim was exposed to beryllium.

In working with the metal or its compounds, the danger arises not from the solid material, which can be handled quite safely at room temperature, but from breathing finely divided material, which might be retained in the lungs: the beryllium content of the working atmosphere must therefore be strictly controlled. Work done in the United States, where the beryllium hazard was first recognized in the early 1940s, has produced recommendations for tolerable (extremely low) atmospheric levels that are internationally accepted. Within the plant, the atmospheric concentration, averaged over an 8 hr working shift, should not exceed 2 μg/cu.m. Further, no matter how low the shift average, no worker must at any time be exposed to an atmospheric concentration of more than 25 μg/cu.m. In the neighbourhood of a plant the atmospheric level, averaged over a month, must be less than 0.01 μg/cu.m.

In order to keep within these very stringent safety-limits, a number of precautions must be taken. The difficulty is enhanced not only by the fact that powdering is an intrinsic part of the processing, but also by the brittleness of the metal. This, aggravated by the need to work without a lubricant in order to prevent contamination, results in the formation of much finely divided material during machining. Machine tools and other equipment are therefore set up in individual enclosures, from which the air is continuously pumped. Handling is done with rubber gauntlets let into the sides of the enclosure.

(*To be continued*)

Parametric Information

(*Continued from page* 160)

so that one can compare all materials of interest in the reactor being analysed.

In summary the combination of variational optimum transport theory analysis and first-order perturbation theory offers a rapid method of calculating parametric information on fast reactors. In the situations studied the accuracy of this method was good over large physical changes in the reactor.

References

[1]DUANE, B. H., " Multi-Energy Neutron and Photon Transport Theory (GE-ANPD Programmes)." *Trans. Am. Nuc. Soc.*, 2-2, (1959).

[2]SHIKHOV, S. B., " The Effect of Dimensional Changes in the Critical Mass of a Fast Reactor, Calculated by Perturbation Theory." *Reactor Science*, 11-2/4, 214 (1960).

[3]LONG, J. K., *et al.*, " Fast Neutron Power Reactor Studies with ZPR-III." A/Conf. 15/P/598 (1958).

[4]DUANE, B. H., private communication.

Institution News

Second Lecture Midland Branch

Professor Joklik

MORE information is now available about the Second Institution lecture to be given by Professor O. F. Joklik at the Junior Institution of Engineers. The lecture will now be delivered at 6.30 p.m. on April 18th and not May 18th as originally announced. "High energy gamma radiation in research, industry and therapy" will be the subject of this lecture.

Prof. Joklik is director of the Department of Atomic Physics, Nuclear Technology and Radiobiology at the Institute of Electronics —Electronic Studies Centre, Rome, Italy. In addition he is in charge of the design, engineering and erection of the world's first large-scale industrial chemical plant utilizing high energy gamma radiation of a multikilocurie cobalt-60 gamma source for the radiation polymerization of methyl methacrylate (organic glass) at Palermo, Sicily. Production from the first unit of this plant is due to start in June, 1961. Prof. Joklik received the gold medal Scientia et Divulgatio, 1960 for work in the fields of radiation research, radiation chemistry and radiobiology.

The Institution lecture will be concerned with design particulars of the radiation polymerization plant with emphasis on the design of the gamma radiation source and its mechanism. In addition, design and techniques of a fully automatic teletherapy unit with electric control of a new gamma convergency cancer treatment will be described and reference made to the combination of the Co60 teletherapy with chemical antiradiation agents and a special oxygen-UV blood treatment for catalase activation as further antiradiation protection.

"From Cobalt to the Cobaltron," is the title of the film which is to be shown after the lecture. This film was awarded the Gran Premio Internazionale, Rome, 1960 at the 2nd International Scientific Films Festival of the 7th International Exhibit and congress on Electronics and Nuclear Energy (Rassegna Internazionale Elettronica e Nucleare).

Midland Branch

Mr. Jones has reported good progress on the formation of the Midland Branch. The first meeting of this branch takes place on March 28th and will be reported in the May issue.

NEW MEMBERS

Elected February 10th, 1961

J. Browne, M
Breaston, Derbys.

N. F. Childs, A
Dorchester, Dorset.

A. Choubevsky, M
Paris, France.

D. P. M. Clayton, A
Holmbrook, Cumberland.

J. E. Cowling, J
Duffield, Derby.

J. S. Daborn, JM
Guildford, Surrey.

B. J. LeT. Darlaston, A
Sutton Coldfield, War'ks.

M. Dennerley, A
Southminster, Essex.

W. J. Drewett, M
Bristol.

S. J. Field, A
Rochester, Kent.

A. J. S. Garner, J
London, E.6.

G. C. Goldring, A
Latchingdon, Essex.

D. N. Gower, M
Tadley, Hants.

G. R. Hodgson, A
Largs, Ayrshire.

C. W. Iliffe, M
Chelmsford, Essex.

K. A. H. Jackson, M
Jarrow, Co. Durham.

A. J. Johnston, J
Southminster, Essex.

J. A. Kimberley, A
Bromsgrove, Worcs.

E. D. Lea, A
Shoreham-by-Sea, Sussex.

E. J. Newman, A
Langley, Bucks.

J. T. O'Shea, A
Iver Village, Bucks.

J. W. Raffel, A
Nr. Basingstoke, Hants.

K. F. N. Savage, A
Dursley, Glos.

H. O. Scott, A
London, N.W.8.

G. E. Shuttleworth, M
Swinton, Manchester.

K. A. Silcox, M
Stourbridge, Worcs.

J. Topping, A
Cumberland.

H. R. Warburton, A
Egremont, Cumberland.

W. J. Wilson, A
Stourport-on-Severn, Worcs.

A. D. Wordsworth, A
London, N.W.1.

Elected March 8th, 1961

B. T. Ballington, A
Derbyshire.

R. S. Bogucki, A
Sidcup, Kent.

S E. Van Den Broek, M
Wickham, Hants.

R. Chetwynd, A
Earley, Reading.

D. D. Davies, A
Tettenhall, Wolverhampton.

J. A. H. Ford, A
Leicestershire.

C. F. Harris, A
Uganda, E. Africa.

A. P. Gupta, M
Cambridge.

J. D. Hibbert, A
Penn, Wolverhampton.

L. E. M. Hill, A
Southminster, Essex.

E. S. Hume, A
Coseley, Bilston.

C. W. A. Maskell, A
Abingdon, Berks.

J. McEwan, M
Blackheath.

G. Millington, A
Chester, Cheshire.

M. W. Molland, A
Bideford, N. Devon.

A. B. Nixon, M
Gosforth, Newcastle.

F. Roberts, M
Oxley, Wolverhampton.

F. W. Turner, M
Annan, Dumfriesshire.

R. G. White, A
Nottingham.

In Parliament

by Peter Lewis—Our Westminster Correspondent

COMPARATIVE average costs of electricity generated/unit for the most modern coal-fired power stations and the new nuclear power station to be built at Wylfa, Anglesey was the subject of a question put by **Mr. Nicholas Ridley** (C., Cirencester and Tewkesbury). The question was answered by **Mr. Richard Wood,** the Minister of Power who explained that the cost for coal-fired stations depended to some extent on the distance from the coalfields but was likely to be about 0.5*d.* to 0.6*d.* a unit. The Minister added that it was too early to give a figure for Wylfa as the tender specification had not yet been issued but the cost was not expected to be above the range he had mentioned. Mr. Ridley then asked if this meant that the break-even point between nuclear and conventional power generation would be reached with the completion of Wylfa power station. The Minister replied that this was not quite true as the capital cost of nuclear stations was very much higher than conventional stations and this point would not be reached for some time. **Mr. A. C. Manuel** (L., Central Ayrshire) asked if the Parliamentary Secretary to the Minister of Power was satisfied that present arrangements for insurance against damage by radioactive contamination were sufficient to cover all possibilities of such damage to persons, livestock and materials, and would the Minister make a statement. The Parliamentary Secretary replied that under the Nuclear Installations (Licensing and Insurance) Act, 1959, operators of nuclear installations, other than the A.E.A., and Government Departments, must insure or provide cover by other appoved means for £5m. The Minister was satisfied that this sum was sufficient to cover all possibilities of damage by direct radiation or radioactive contamination which could arise from any foreseeable accident. If £5m. was insufficient to meet claims, the Act provided for Parliament to decide how the claims should be met.

Mr. Roy Mason (L., Barnsley) asked the Parliamentary Secretary for Science when he would introduce a system of standard markings for containers of radioactive materials so that, in the event of an accident, police and firemen could quickly assess the degree of danger. In a written reply, **Mr. Denzil Freeth** said that packages of all radioactive isotopes supplied by the Atomic Energy Authority are distinctly marked with the word "Radioactive." Standard markings for containers, including the trefoil which is now incorporated in a British Standards Institution design, circulated for comment preparatory to the introduction of a specification, were under international discussion. The International Atomic Energy Agency had prepared draft recommendations for the transport of radioactive materials upon which it was intended to base regulations in this country to be issued by the Ministry of Transport.

In a debate on fuel and power **Mr. Ray Gunter** (L., Southwark) gave a gloomy picture of the world's reserves of fuels for power and while conceding that nuclear power would play a very formidable role in power supplies, he doubted if it would amount to much for at least 50 to 75 years.

The training of science teachers and scientific education in general is keenly watched by Members and **Mr. William Whitlock** (L., Nottingham N.) asked the Minister of Education what steps he proposed to take to improve the supply of science teachers. **Sir David Eccles** replied that the present campaign to attract teachers back to the schools paid special attention to science teachers. In the training college expansion programme, special emphasis had been placed on more and better science courses. Sir David went on to say that the expansion of universities should also provide more teachers and he was taking steps to interest undergraduates in teaching as a career.

Later in the month, **Mrs. Judith Hart** (L., Lanark), asked Sir David what consultation he had had with schools and universities concerning science specialization in school sixth forms. In a written reply Sir David said that the complex problem was being actively discussed with the schools, professional associations, the universities, the Secondary School Examinations Council and the Examining Bodies. All were concerned to prevent premature and excessive specialization in science as in other subjects.

Mr. Austen Albu (L., Edmonton) asked Sir David if he would publish in the Official Report the number of students in each of the years of the courses for the Diploma in Technology, distinguishing the subjects of their courses. Sir David said that the National Council for Technological Awards had given him the following information:

The number of courses leading to the Diploma in Technology, together with the number of students enrolled under subjects (January, 1961)

Subject	Number of courses		Number of students enrolled					
	Full time	Sandwich	1st year	2nd year	3rd year	4th year	5th year	Total
Aeronautical Engineering	—	9	83	90	84	12	—	269
Applied Biology	1	2	38	23	17	11	—	89
*Applied Biochemistry	1	—	13	6	2	—	—	26
*Applied Pharmacology	1	—			5	—	—	
Applied Chemistry								
Chemical Technology	2	12	219	150	94	49	—	512
Industrial Chemistry								
Building	—	1	12	12	9	—	—	33
Chemical Engineering	2	3	54	56	40	10	2	162
Civil Engineering	3	4	86	79	11	—	—	176
Electrical Engineering	2	15	467	403	333	207	4	1,414
Instrument and Control Engineering	—	1	14	9	9	8	—	40
Mathematics	1	6	74	53	30	12	—	169
Mechanical and Production Engineering	1	18	493	459	333	185	4	1,474
Metallurgy	1	3	36	40	32	20	6	134
Physics	1	10	178	127	97	62	—	464
Naval Architecture	—	1	2	5	—	—	—	7
Totals	16	85	1,769	1,512	1,096	576	16	4,969

*The first two years of these courses are common.

Book Reviews

Fast Reactor Cross-Sections, A Study leading to a 16 Group Set, by S. Yiftah, D. Okrent and P. A. Moldauer. Published by Pergamon Press (Oxford, London, New York, Paris) in the International Series of Monographs on Nuclear Energy (General Editor J. V. Dunworth) as Voumle 4 of Division II (Nuclear Physics). Size $5\frac{3}{4}$ in. $\times$ $8\frac{3}{4}$ in. $\times$ 130 pp. Price £1 15*s.* 0*d.*

Many multigroup cross-section sets have been formulated in the past, most of them reflecting a mixture of direct microscopic measurements and empirical adjustments, the latter usually determined so as to fit a group of critical experiments reasonably well. Such sets have generally been presented without detailed justifications followed by a comparison with integral experiments. Although valuable, this procedure leaves the user without an assessment of the reliabilities of the constants employed, and, moreover, makes it difficult to incorporate new microscopic measurements as they come in. The main purpose of the study under review is to construct a new multi-group cross-section set in which an effort has been made to explain and document all choices and assumptions made. These constants were arrived at by a review of the available experimental data together with theoretical estimates where such data were not available. Gaps, conflicts and inconsistencies in the data are pointed out and, although no attempt is made to produce a complete bibliography, data available up to March, 1960, are generally included. Data are presented on 59 isotopes of 20 elements, which are divided into four classes: fissile and fertile ($232 \leqslant A \leqslant 242$); heavy structural and coolant ($90 \leqslant A \leqslant 210$); medium structural ($45 \leqslant A \leqslant 70$); light coolants, fuel additives and poisons ($10 \leqslant A \leqslant 40$). A convenient pull-out table summarizes the main characteristics of these materials. The main body of the book is essentially a collection of tables and graphs, the connective text being in the nature of a commentary on these. After a short introductory chapter, Chapter II gives the group structure of the present day—eight groups below, and eight above 100 KeV, which is roughly where the flux peaks in large fast reactors—and compares this with the groupings used in previous surveys. The data of the next three chapters are the " meat " of the bock, the relevant headings being: Ch. III, Fission Process (sections on Fission cross-sections, Number of prompt neutrons per fission, Fission neutron energy spectrum); Ch. IV, Neutron Scattering (sections on Inelastic scattering, Elastic scattering, Elastic moderation); Ch. V, Neutron Capture. The remaining chapters discuss the averaging methods, gaps and inconsistencies in the microscopic data, and comparisons with integral experimental data. As the results of critical experiments were not used in assigning values to the microscopic parameters, or in choosing within experimental uncertainty, the comparison made in the final section gives a measure of the present degree of agreement between microscopic and integral experiments in fast reactor physics. The integral experiments available for comparison related to systems containing for the most part U-235, U-238, aluminium steel and graphite in varying amounts. For such systems the microscopic data of the present set proved consistently too reactive, predicting smaller critical masses than were observed. Predicted reaction ratios were in fairly good agreement with experiment, indicating reasonable success in matching spectra, although consistent deviations were noticed here, too. The book contains a veritable mine of information and may well become a " bible " to workers in fast reactor physics. No doubt as new data accumulate a new edition will be required, and in this the opportunity could be taken to make some small but worthwhile improvements in the presentation. For example, the sentence which begins at the bottom of page 9 ends at the top of page 36 —there being 25 pages of tables in between! A little editorial ingenuity could surely avoid this. Again on page 36, and generally throughout Chapter III, the notation could be simplified to avoid such expressions as: $\sigma_f Pu^{240}/\sigma_f Pu^{239} \approx \sigma_f Np^{237}/\sigma_f Pu^{239}$. Why not $\sigma(Pu240)/\sigma(Pu239) \approx \sigma(Np237)/\sigma(Pu239)$? Since the whole chapter is about fission there is no ambiguity in dropping the suffix f, and the re-arrangement of the other symbols to avoid superscripts (and superscripts to superscripts!) would be easier on the reader as well as the typographer. A subject index could also with advantage be included in any future edition.

J. W. GARDNER

Management of Nuclear Materials, edited by Ralph F. Lamb. Published by D. Van Nostrand Co., Inc. 514 pp., illustrated.

This publication is effectively a survey of the nuclear materials industry in U.S.A., and gives a reasonably full picture of the processes involved and the type of equipment in general use for handling and processing materials of this kind. The accent throughout is on the problems inherent in controlling and accounting the materials in use, in view of their high cost and the potential criticality hazard involved. The high degree of refinement to which the techniques have been raised in order to achieve the control necessary is probably not directly applicable to any other industry but the general principles followed could be of value. There is some apparent repetition where the same principles of control are applied to very similar processes; this, however, gives a more complete picture of the processes in use in the industry. The diagrams and illustrations are well chosen and well reproduced. The physical quality of the publication is high, and makes for easy reading. Only one typographical error was apparent (on p. 368 where " tyocycle " should presumably read " two-cycle "). In all, the book could provide a useful starting point for those about to enter the nuclear materials industry, or others who might wish to know a little more about it. On the other hand, those who are already in the industry and who are familiar with the handling, control and processing problems will find little to add to their knowledge of the control methods available and in use. W.L.S.

Kempe's Engineers Year Book, 66th Edition. 2 Vols.: Vol. 1, 1,324 pp.; Vol. 2, 1,403 pp. Morgan Bros. (Publishers), Ltd. Price 87*s.* 6*d.*

This useful reference which appears to be so effortless must entail considerable revision each year. For instance, the current edition contains revised information in almost all of its 84 sections, with some chapters being completely rewritten. Among the new items is a full range of equivalents and conversion factors for Metric to Imperial units, and Imperial to Metric. Because it is constantly kept up to date, it has become a standard reference, useful to all sections of engineering, civil, mechanical, electrical and nuclear—a complete reference library in itself.

The third volume of the **Directory of Nuclear Reactors** published by the International Atomic Energy Agency is now available. This volume is devoted to research, test and experimental reactors. Information is presented in a similar way to the first two volumes and provides an easy reference. It is intended to issue supplements to this volume and to the previous ones in order to keep the directory up to date. The directory is not intended to provide complete details as required by the specialist, but rather to help those who often need " to refer to pertinent features of various reactors and compare them easily and quickly." The illustrations do not cover construction and design in great detail but are meant to give a general idea of the layout of reactor components and associated equipment. Useful conversion tables are provided to deal with the various measurements used in the original projects.

PEOPLE

The reorganization of the UKAEA has resulted in a number of new staff appointments. These appointments will take effect from April 1st, 1961. On this date, **SIR WILLIAM COOK,** at present Member for Development and Engineering, will become Member for Reactors and **SIR LEONARD OWEN's** responsibilities will be extended to cover the Production and Engineering Groups as Member for Production and Engineering. At the same time **SIR WILLIAM PENNEY** will be appointed deputy chairman with prime responsibility for scientific and technical co-ordination throughout the Authority. **DR. F. A. VICK,** OBE, will continue as director of Harwell but will also be director of the Research Group, **MR. R. V. MOORE,** GC, will be managing director of the Reactor Group, **MR. J. B. W. CUNNINGHAM** will be managing director of the Engineering Group and **MR. J. C. C. STEWART,** CBE, managing director of the Production Group.

Sir William Penney succeeded Sir John Cockcroft as Member for Scientific Research in July, 1959, before which he was Member for Weapons Research. He is 52 and has two sons.

Dr. Vick was appointed deputy director of Harwell in 1959 and became director on September 1st, 1960. He is a member of the Scientific Advisory Council of the Ministry of Power and a member of the University Grants Committee. Dr. Vick is 49 with one daughter.

Mr. Moore was one of the first engineers to join Harwell where he worked from 1946 to 1953. He was Group Leader for the construction of BEPO and also for the design studies of the PIPPA type reactor on which Calder Hall is based. He went to Risley in 1953 and then became chief engineer of Calder Hall in 1955.

In 1956 he was appointed assistant director for civil reactors and from then until 1960 he held various appointments connected with reactors. In 1960 Mr. Moore became deputy managing director, projects, in the Development and Engineering Group. Mr. Moore is 44 and has three sons.

Mr. Cunningham started his career with the Authority as chief design engineer, Risley, in 1945 and since then has been deputy director, reactors, and then for industrial power. In 1958 he was appointed director of industrial power and in 1959 deputy managing director, Technical Production Group, Risley. Mr. Cunningham is 49 and has three daughters.

Mr. J. C. Stewart spent a short time directly after the war working on the atomic energy plant at Chalk River, Canada. After this he became one of the Harwell pioneers and worked on the first reactor to be built in the U.K. In 1955 when the Technical Policy Branch was formed, Mr. Stewart was appointed director. This branch carried on the overall planning work of the technical activities and has also covered the commercial activities of the Group and its interest in international relations. In February, 1958, Mr. Stewart became deputy managing director of the Industrial Group. When this group was divided into two, Mr. Stewart became deputy managing director, operations, Production Group, Risley. Mr. Stewart is 44 and has one daughter.

MR. C. H. WEAVER has been elected president of the Atomic Industrial Forum, Inc. Mr. Weaver has served as a director of the Forum since 1955 and has been chairman of its budget committee for the past two years.

MR. J. A. CROFT has now been appointed chairman of Crofts (Engineers), Holdings, Ltd., and its subsidiaries. He succeeds his father, the late **SIR ARTHUR CROFT.** Mr. Croft has been deputy chairman and managing director since January 1st, 1954.

Mr. J. A. Croft

MAJOR F. D. OUTRIDGE has been appointed assistant to Capt. R. A. Villiers, director of the Scientific Instrument Manufacturers' Association. Major Outridge will be responsible for the publicity and exhibitions of SIMA in the U.K. and overseas; he will also act in a secretarial capacity to the main committees.

MR. M. FALK, managing director of Nuclear Research Applications, Ltd., has been invited to join the "export action now" committee of the Institute of Directors. The committee was formed towards the end of 1960 on the initiative of Lord Chandos.

It has been announced that **DR. W. J. STROMQUIST** has succeeded **MR. H. L. WEINBERG** as resident manager of the SM-1 nuclear power plant at Fort Belvoir, Virginia.

MR. S. A. CLODD has been appointed to the board of directors of E. K. Cole, Ltd. Formerly works manager and executive director, Mr. Clodd joined Ekco during the war as material controller. He was appointed works manager in 1950 and became an executive director in 1957.

MR. R. G. HOOKER, JP, has been appointed deputy managing director of K & L Steelfounders and Engineers, Ltd., Letchworth, an important member of the George Cohen 600 Group which operates one of the country's largest and best equipped steel foundries. Mr. Hooker, who is 39, served his apprenticeship with Phillips Electrical, Ltd. In 1951 Mr. Hooker joined the Brush Group and in the following year was appointed general works manager of J. & H. McLaren, Ltd., Leeds; in 1954 he joined the board of Brush Electrical Engineering Co., Ltd., as works director, being promoted to general manager in 1957. While with Brush in Loughborough, he served as chairman of the Productivity Association, a member of PERA technical policy committee, and of the Engineering Employers Central Conference Committee at York.

As a result of the Ekco-Pye merger it has been announced that **MR. N. A. TWEMLOW,** MBE, director of Pye, Ltd., has been appointed to the board of E. K. Cole, Ltd., and **MR. W. M. YORK,** commercial director of E. K. Cole, Ltd., becomes a director of Pye, Ltd. Mr. Twemlow is a director of a number of the Pye group of companies. He has previously been connected with Ekco, with whom he spent a short time before joining Pye in1934. Mr. York joined Ekco in 1932. He is a director of a number of the companies which form the Ekco Group and a director of Radio Industry Exhibitions, Ltd. He was elected vice chairman of BREMA in April, 1960.

Three Soviet scientists who have been working at the CERN laboratories in Geneva under an agreement reached in 1960 with the Dubna research institute, have returned to the Soviet Union. Three CERN scientists have now gone to the Dubna Institute under the exchange agreement and will remain there for about six months. They are **W. N. COTTINGHAM,** U.K., **E. FISCHER,** Germany, and **M. SCHNEEBERGER,** Switzerland.

VASSILY EMELYANOV, chairman of the U.S.S.R. State Committee for Atomic Energy, has been awarded the Order of Lenin on his 60th birthday for his services in developing Soviet nuclear science and technology. He is a member of the scientific consultative committee of the IAEA.

The Council of The Institution of Mechanical Engineers has announced that the secretary, **MR. B. G. ROBBINS,** is to retire on June 1st, 1961, and will be succeeded by **MR. K. H. PLATT.** Mr. Platt, at present deputy secretary of the Institution, was educated at Shrewsbury School and the University of Glasgow, where he graduated in Mechanical Engineering. After receiving his practical training and gaining experience in industry, he became a lecturer in mechanical engineering. During the last war he served in the RAOC and REME, being made MBE for his services in Malta, and held the rank of Major. After the war, Mr. Platt was again associated with engineering education and training, both in industry and with the Ministry of Education (as HMI). He joined the Institution staff in November, 1952, was appointed assistant secretary in May, 1953 and deputy secretary in January, 1956. He became an associate member of the Institution in 1937 and a member in 1953.

Equipment and Materials

Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

Programme controller

Photoelectronics (MOM), Ltd., have announced a new Counter Batcher Programme Controller, Type CBP. This unit has a revolutionary approach to the problem and has overcome the many disadvantages associated with cold cathode decade counting tubes previously used for this type of operation. It consists of a number of plug-in decade units which are fully transistorized and constructed on a printed-circuit enabling rapid changing of units to provide programming sequences for any type of installation. With this type of construction eliminating all mechanical switches the speed of operation, both for straightforward counting and with full preselection of batch quantities, is at the rate of 3,000/sec. Any number of decade units can be used in one unit to provide totals to any number of digits. The equipment is provided with a number of pre-batch impulses for warning or other programming control and indication of count is provided by a series of neon tubes illuminating their respective numbers in turn. Any conventional method of input can be used with this unit, including photo-transistors, and suitable power supplies are incorporated for operating these. It can also be connected to the mains and use the frequency as a time base with multiple outputs for programme control. **(APR 1)**

Double-beam oscilloscope

Solartron Laboratory Instruments are producing a rackmounted double-beam oscilloscope, CD 1016. It has two identical Y amplifiers, bandwidth of d.c. to 5 mc/s (−3 dB), with a rise time of approximately 70 mμsecs. Nine calibrated sensitivity ranges, switched in 1-2-5 sequence, cover 100 mv/cm to 50v/cm with ±5 per cent. accuracy. In addition a fine control gives continuous coverage up to approximately 100 v/cm. The integral a.c. preamplifier preceding Y_2 gives six additional sensitivity ranges with a maximum sensitivity of 1 mV/cm. The input impedance is 1 MΩ and 30 pF. Inputs may be "floated" up to 500v (+ve or −ve) relative to chassis for displaying signals isolated from earth.

The time base covers 1 cm/μsec to 2 cm/sec in 18 calibrated ranges, in 1-2-5 sequence with ±5 per cent. measuring accuracy. A fine control with a calibration position gives continuous coverage to 1 cm/sec. The maximum sweep speed of 5 cm/μsec may be obtained by using X expansion. The oscilloscope may be triggered internally or externally (+ve or −ve) on TV frame, TV line, Auto or Normal modes. "Level" and "Stability" controls permit accurate and reliable triggering at a selected point on the displayed waveform.

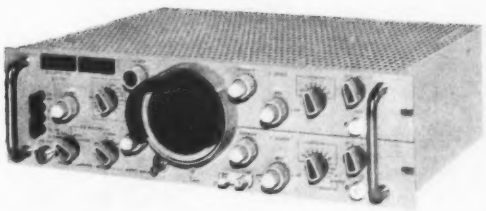
A "bootstrap" type time-base is employed giving a linearity better than 1 per cent. The time-base waveform (10 V pk-pk) is available at a socket on the front panel.

The X amplifier (bandwidth d.c.—750 kc/s) has a continuously variable sensitivity from 0.15v/cm to 1.5v/cm. Direct access to this amplifier is available for external signals.

A 30v bright-up pulse derived from a separate bi-stable circuit, d.c. coupled to the cathode ray tube, gives bright displays at all sweep speeds. Provision is also made for external brightness modulation.

A square wave of ½v pk-pk ± 1 per cent., at mains frequency, is available for calibration of the time-base and Y sensitivity.

Stabilized E.H.T. enables calibration accuracy to be maintained regardless of brightness levels. A 3½ in. diameter double gun c.r.t. type 3AZP31 is used.



Solartron double-beam oscilloscope

Mains input 100-125v/200-250v, 45-66 c/s. Dimensions of the oscilloscope are 5¼ in. × 19 in. × 14½ in. overall (13 in. behind front panel). Weight 25 lb. **(APR 2)**

Silicone seals

A series of seals have been developed by Dowty Seals, Ltd., to meet nuclear engineering requirements.

They are based on the silicone compound S.E.M. 895, which possesses normal sealing qualities and is also heat resistant. This material acts as a shield against radiation, maintains its stability over a wide thermal range and resists compression set.

These seals have been produced after an extensive programme of tests, including irradiation of specimens by high energy electron beams. The range includes "O" section rings, having long life when used in temperatures up to 150°C., and rectangular section seals for temperatures up to 175°C., and up to 250°C. for short periods.

Cut along here

To: NUCLEAR ENERGY

147 Victoria Street, London, S.W.1

Please send further details of the following items in the EQUIPMENT & MATERIALS *feature for April, 1961*

Item No's ....

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IS THIS ENQUIRY CONFIDENTIAL? YES | NO

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The new seals are especially suitable for use in close vicinity of reactor vessels, *e.g.*, stand pipes and control equipment, where radiation is present and temperatures high. Another application is with " glove boxes " in which radioactive materials are handled at the Harwell Atomic Energy Research Establishment. **(APR 3)**

Neutron generator

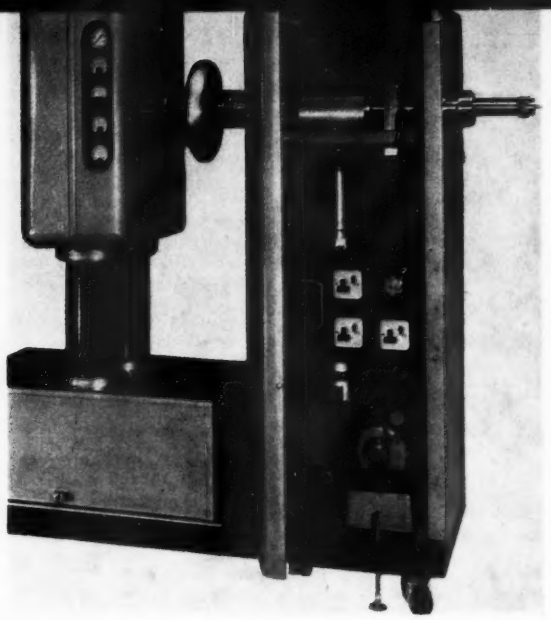
The neutron generator type NGH 150 produced by 20th Century Electronics is now available. It has been designed to provide a source of neutrons of variable intensity and energy for use in the laboratory. The main characteristics of the instrument are high neutron output, experimental flexibility and continuous or pulsed operation.

A D.T. reaction is used to produce 14 MeV neutrons. The deuterium ions are accelerated on to a tritium target, and the neutron output under continuous operation is of the order of 10^{10} neutrons/sec. Fast neutrons can be moderated to produce thermal neutrons. The unit is continuously pumped and has an accelerating potential of 150 kV.

In addition to this application as a neutron generator the instrument can be quickly adapted to provide accelerated ion beams of deutrons or protons for other nuclear physics applications.

This instrument can also be used to irradiate samples for radioactivation analysis techniques, in analysing high purity materials.

The prototype instrument is currently used to test fission chambers and other neutron detectors. **(APR 4)**



Neutron generator type NGH 150 produced by 20th Century Electronics, Ltd.

X-ray gauge

The XactRAY, an X-ray gauge for measuring rolled and extruded products, produced by the Daystrom Co. of America, is now available in the U.K.

The gauge consists of three basic elements, an X-ray generator, which directs controlled beams of X-rays through the material being measured, the X-ray incident unit or pick-up, which converts the transmitted electromagnetic energy into an electrical signal, and an electronic console, which computes and converts the signal into meter indications. Dimensional changes are displayed as a deviation from the pre-set nominal thickness on an indicator calibrated in any unit of density or thickness.

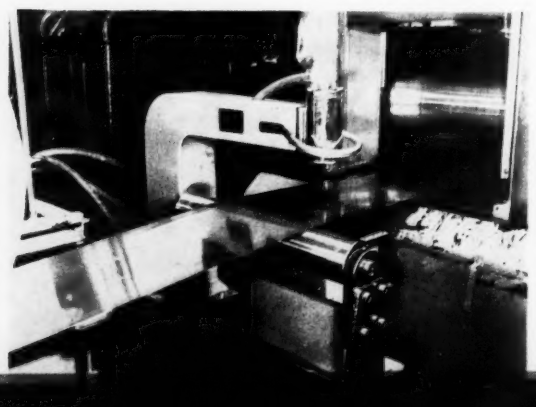
A signal proportional to thickness deviation is available to operate automatic thickness control, data logging devices, and strip chart recorders for permanent records, or marking of off-gauge material.

Both X-ray generator and pick-up unit have been designed to operate under severe mill conditions and are sealed against oil, water and steam. In situations where they are liable to mechanical damage, special armoured gauges are available.

The electronic console is preferably located in the motor room within 100 ft of the X-ray source. Positive filtered air pressure is, however, maintained within the cubicle to ensure reliability in locations where airborne dust and dirt are prevalent. All electronic components are mounted on a special hinged modular chassis to permit inspection during operation.

A patented feature of the XactRAY is a device for inserting metal standards into the X-ray beam for calibration purposes. These standards are enclosed in a sealed chamber directly above the X-ray source and are inserted into the beam by rotary solenoids. The system enables an operator at a remote position to select the exact thickness to be measured in increments as small as 0.0001 in. Normally, the XactRAY can be set to a new thickness range in less than 10 sec, including time for recalibration. Where materials of different densities are to be gauged, a multi-position selection switch, which automatically compensates for any variation of density, is provided.

The X-ray generator mounted below the material emits a thin pencil beam of X-rays. Only a tiny proportion of this beam emerges from the strip to energize the pick-up unit and is approximately the same for all X-ray sources and materials; this is due to the inherent flexibility of the generator, the X-ray intensity being adjusted to the material and thickness to be measured, i.e., a small output for thin or low density materials.



Daystrom XactRAY gauging carriage in position

This control of intensity of the pencil beam and the high pick-up sensitivity guarantees complete safety of the operator against stray radiation. No special radiological screening is necessary and even at the highest X-ray settings, the radiation level at 1 ft from the beam is much less than accepted safety limits. **(APR 5)**

Gamma monitoring

Both linear and logarithmic instruments have been introduced by AEI Instrumentation Division for high accuracy area monitoring of gamma radiation.

To obtain optimum flatness of gamma energy response, both types employ a large and sensitive ionization chamber filled with argon and air. An unusual feature, incorporated in both instruments, is the use of an electrometer valve as a cathode follower. Other features are transistorized circuits (excluding the input electrometer stage) and an instrument failure system. The latter overrides the alarm trip and can be used to energize a visual or audible warning differing in character from the radiation alarm, thus eliminating the main source of false radiation alarms. Failure to safety is ensured, the relays being de-energized in the alarm condition.

The instruments are contained in splash-proof cast-aluminium desiccated cases, and the ionization chamber may be mounted remotely or on top of the case. Provision is made for remote recorder of meter facilities. To prevent accidental or alteration, all setting controls are inaccessible and can only be reached by withdrawing the chassis from the case.

The linear instrument (type G.M.1) has four measuring ranges, 0-125 mR/hr, 0-250 mR/hr, 0-500 mR/hr, 0-1,000 mR/hr, with a relative accuracy of ± 3 per cent. f.s.d. and stability, over seven days, of better than 2 per cent.

The type G.M.2 instrument has a measuring range extending from 0.1 mR/hr to 10 mR/hr calibrated logarithmically over 5 decades. It has a zero indication, a relative accuracy of ± 3 per cent. f.s.d., and a stability of ± 2 per cent. over seven days. **(APR 6)**

NUCLEAR NOTES

Winfrith monorail

BRITISH Monorail, Ltd., have been awarded a contract for the design, manufacture and installation of a completely automatic remote-controlled monorail installation to handle fissile materials at Winfrith AEE. The scheme permits remote selection of material from any of the seven assembly bays in the fissile material stores and its delivery to any one of 12 experimental stations in the reactor physics hall. Loads are picked up and transported by electric hoists suspended from powered carriages which run on a system of overhead monorails.

VERA achieves criticality

A NEW low power reactor, VERA (Versatile Experimental Reactor Assembly) recently achieved criticality at AWRE, Aldermaston. VERA is to be used in reactor physics experiments to improve nuclear data and methods of calculation for fast critical assemblies. More information on these systems is required for many problems relating to the safety of storage and processing of fissile materials and for the fast reactor development programme. The reactor includes a core region of thin-walled steel fuel tubes surrounded by a natural uranium reflector, the whole forming a cylinder 4 ft high and 5 ft in diameter. The fuel tubes are loaded with fissile and diluent material plates 1.7 in. square and $\frac{1}{8}$ in. thick. By appropriate loadings the composition and size of the reactor core may be varied to examine the nuclear importance of materials over a wide range of neutron energies. The reactor is designed to separate into two parts for safe loading, the two halves being brought slowly together by remote control. An associated accelerator enables neutron bursts to be generated for measurements of reactivity and time-dependent behaviour. The reactor is located in a large concrete cell which is sealed during operation. As the power will not exceed 100w, special cooling is not required.

Organization reviewed

THE REVIEW of the organization of the UKAEA which was recommended in the Select Committee's report presented in July, 1959, has now taken place and it has been decided to make a number of changes to take effect from April 1st, 1961. Sir William Penney is to be appointed to the new post of deputy chairman with responsibility for scientific and technical co-ordination throughout the Authority. Design and development of nuclear reactors is to be the responsibility of one group. The structure of the Development and Engineering Group is to be modified for this purpose and it will be known as the Reactor Group. This group will also be responsible for relations in the reactor field with industry at home and overseas, and it will control major development facilities necessary for its work. The Winfrith Research Establishment will be transferred from the Research Group to Reactor Group. Responsibility for the design and construction of plant, works and buildings will be transferred from Development and Engineering Group to a new Engineering Group which will also take over from the Production Group responsibility for the design and inspection of fuel elements for production purposes. Sir William Cook, at present member for Development and Engineering, will in future be known as member for Reactors. Sir Leonard Owen will now be responsible for the Production and Engineering Groups and will be known as the member for Production and Engineering.

Flying to save time

THE Nuclear Power Group have recently rented a Piaggio P.166 executive aircraft from McAlpine Aviation. The aircraft is to be based at Ringway Airport, Manchester, and will be used by the group to ferry executives from one part of the country to another. Expansion of the group's activities has meant that the executive must spend much more time in travelling and it is hoped that the use of this aircraft will save valuable time in moving from site to site.

£55,000 expansion

NUCLEAR INSTRUMENTS (G.B.), Ltd., are to expand for the second time in two years. A new £55,000 factory is to be built for them at Sighthill Industrial Estate, Edinburgh, where they have occupied a small factory for the past two years. The new plant will have 25,000 sq.ft with room for expansion to 50,000 sq.ft. The initial development includes laboratories, workshops and a two-storeyed administrative building. Clean air filtering is a particular feature of the new laboratories.

Prototype reactor

Prototype atomic reactor exhibited recently at Capitol Hill by Atomics International for the Joint Congressional Committee on Atomic Energy. The reactor has been used in tests and was built by the company as part of the SNAP programme. The unit weighs about 200 lb and has generated 225,000 kWh to date, which is equivalent to full time operation at design power for six months

Three-stage accelerator

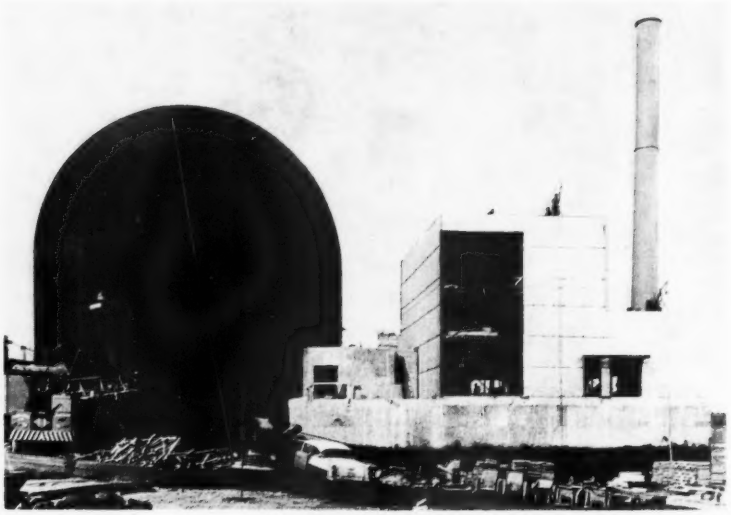
THE FIRST three-stage tandem Van de Graaf 17.5 MeV accelerator has been purchased by the University of Texas for its new Science Engineering Centre. This machine plus a 4 MeV " atom-smasher " is to be supplied by High Voltage Engineering Corporation. The particle accelerators plus instrumentation will cost $1.8m. Research work using these machines will be directed by a Briton, Dr. Bernard B. Kinsey. In the 17.5 MeV machine a Van de Graaf accelerator will inject high energy (5.5 MeV) negative ions into a two-stage tandem accelerator. Within the tandem, by a method called charge-exchange, the negative ions are stripped of electrons and converted into positive ions which are further accelerated in the last stage of the

NUCLEAR NOTES

huge machine. There they reach the energies needed to investigate the little-known structure of complex atomic nuclei. A 4 MeV unit will provide intense quantities of monoenergetic neutrons for probing the atomic nucleus with these particles and for general teaching purposes. It will be particularly useful for production of certain radioactive isotopes with short half lives and for analytical and engineering applications. Radiation damage studies, activation analysis, nuclear reactor design and engineering research are among the many possible fields of application.

Military safeguards

THE IAEA's board of governors has recently approved the principles and procedures of safeguards to prevent a diversion for military purposes of assistance given to member states. These safeguards are only designed for requirements anticipated in the immediate future and cover reactors with a thermal output of less than 100 MW. Material used and produced in these reactors is covered. Separate arrangements will be made by the Agency with the states concerned but generally speaking the following provisions will be made: (*a*) examination and approval of designs by the Agency; (*b*) maintenance by the state concerned of an agreed system of records; (*c*) submission to the Agency of routine and special reports; and (*d*) inspections by the Agency.

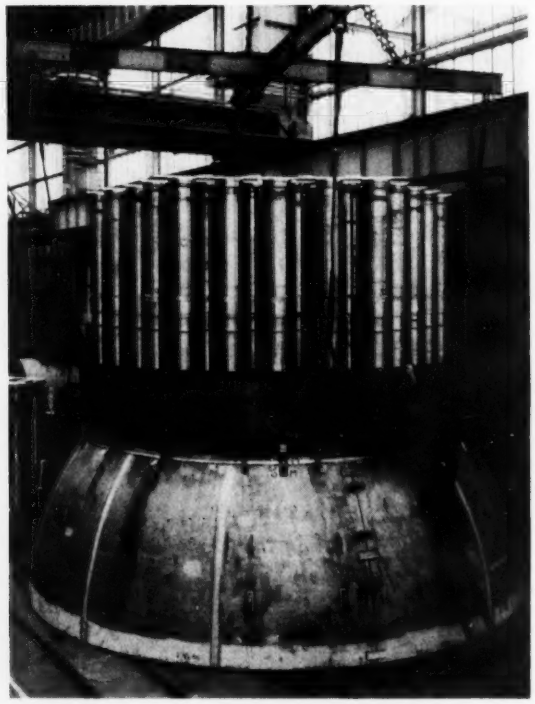


Power Plant at Piqua

First American atomic power plant owned by a municipal utility. This 11,000 kW station is being built at Piqua, Ohio, by Atomics International as part of the USAEC's demonstration programme. The dome-shaped housing will contain an organic moderated and cooled reactor while the process equipment, control room and offices will be housed in the building on the right. The station is due for completion this summer

New Canadian foundation

THE uranium-producing companies of Canada have joined together to form the Canadian Uranium Research Foundation, the stated objective of which is " to provide for research in the use of the products of the uranium industry, to disseminate information relative to such products and to promote, foster and stimulate the uranium industry." Research by the Foundation will be in non-nuclear fields. Member companies have agreed to contribute a minimum of $250,000 a year. Mr. F. A. Forward is the director of research.



Dome for HERO

Top dome of the HERO reactor vessel assembled at the South Works of Ashmore, Benson, Pease & Co., Ltd., Stockton-on-Tees. The vessel has now been sent to the Windscale works of the UKAEA. It is one of the largest stainless steel vessels to be built in the U.K. and has been manufactured to very fine tolerances

Man in the street

THE object of the recent UKAEA exhibition in Brighton was to interest not only the scientist but also the man in the street. The exhibition was divided into three sections, an illustrated representation of the make-up of the atom, Britain's atomic power programme and the use of radio-isotopes. The exhibition included a cut-away model of Calder Hall on which demonstrations were given of atomic power station operation. Products of Sussex firms engaged in the nuclear industry were also on display. The exhibition was opened by Sir John Cockcroft.

In case of accident

THE IAEA has given preliminary consideration to a plan for mutual assistance in the event of radiation accidents. The object is to facilitate rapid provision of adequate emergency assistance to any member who may need to deal with health hazards from ionizing radiation. The board of governors have decided to establish an inter-governmental committee consisting of representatives from 14 countries to draft an international convention on civil liability for nuclear damage. The draft is already drawn up by a panel of experts and comments on this draft by member governments will be taken as a basis for the committee's work.

NUCLEAR NOTES

TRIGA for university

THE Government of West Germany has made 1,530,000 DM available to Johannes Gutenberg University for the purchase of a TRIGA Mark II reactor. This reactor will have a normal power level of 30 kW (thermal) and can be pulsed for fractions of a second to high peak power levels to provide intense but self-limiting pulses of neutron and gamma rays for studies of nuclear fission and of radiation effects on materials.

Viet-Nam agreement

AN AGREEMENT between Viet-Nam and France for the exploitation of the peaceful uses of atomic energy was signed recently. Signatories were Eric de Carbonnel, secretary general of the French Foreign Ministry; Pierre Couture, director of the French Atomic Energy Commission; Dr. Pham Khac Hy, Vietnamese Ambassador in Paris; and Professor Buu Hoi, director of the Vietnamese Atomic Energy Office. The agreement provides for exchange of information on the peaceful applications of atomic energy in its scientific and technical spheres, the supply of nuclear material and equipment and the exchange of students, specialists and professors.

Nuclear power jets

TWO modified turbojet engines have recently been started and brought up to normal operating conditions using nuclear power alone by General Electric of the U.S.A. Previously these engines had been started by chemical means and then transferred to nuclear power when they had obtained normal operating conditions. The company now hope to have a high-performance nuclear turbojet power plant available for flight testing in the mid-1960s. This particular test was the last in a series of Heat Transfer Reactor Experiments (HTRE) spread over the last four years. The next step is the design and ground and flight testing of such a power plant.

Soviet "Atoms for Peace"

Atomic energy will occupy 13,988 sq.ft out of a total area of 224,884 sq.ft at the Soviet Trade and Industry Exhibition to be held in London from July 7th to 29th. "Atoms for Peace" is the title of the atomic energy section, a model of which is shown here

New fuel available

URANIUM monocarbide, a new fuel for high temperature nuclear reactors, is now available in laboratory quantities from Vitro Corporation of the U.S.A. The material is available as granules or as high density spheres of from 200 mesh to $^{5}/_{16}$ in. diameter and combines high thermal conductivity, melting point and uranium density with an excellent irradiation stability.

Novo-Voronezh station

WORK on the new Soviet atomic power station at Novo-Voronezh on the River Don has reached an advanced stage. Assembly work has started on the first turbine and on the crane to be used for lowering the reactor into its well. The station is designed with a capacity of 420,000 kW. The reactor will be of the water-moderated type. The reactor core will be enclosed in a steel case about 13 ft across × 40 ft high. The station will be fully automated. Construction work started three years ago and the first section, consisting of three 70,000 kW turbines, will go into operation in 1962.

New commission

A NUCLEAR energy commission has been set up in San Salvador under the name Comisión Salvadoreña de Energía Nuclear (COSEN). It will consider the applications in industry, medicine and agriculture of radioisotopes and nuclear energy.

Canberra conference

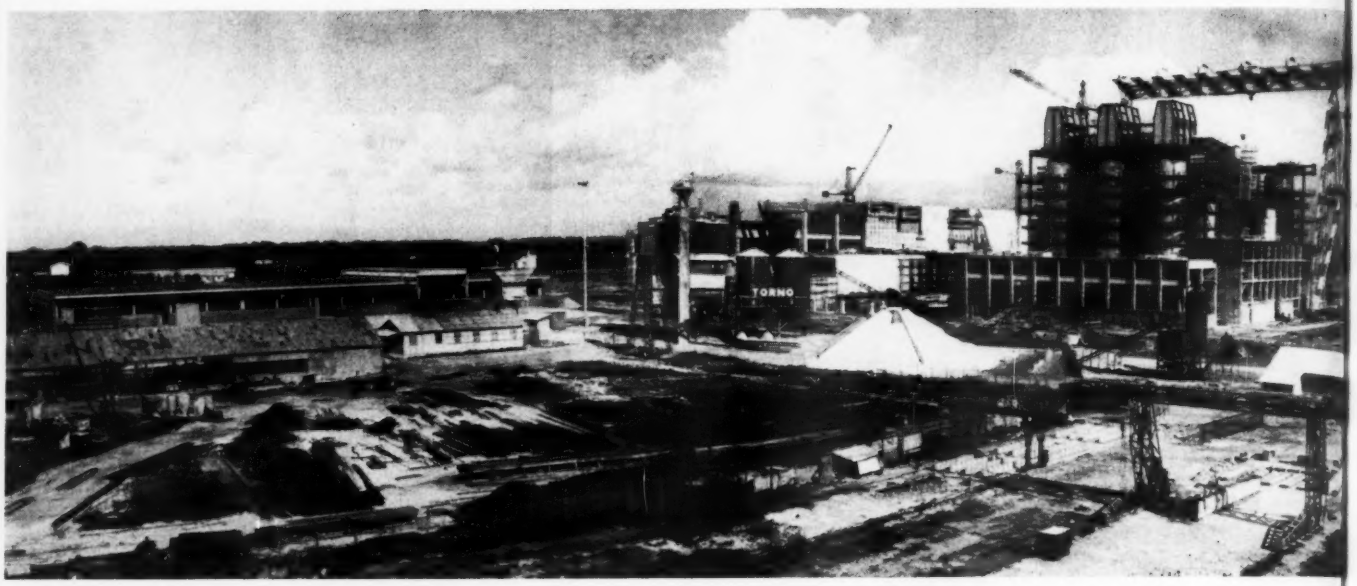
A MAJOR nuclear physics conference was held recently at the Australian National University in Canberra. It was attended by over 70 nuclear scientists from Australian universities, the Atomic Energy Commission, and abroad. They included British physicists Professor D. H. Wilkinson, of Oxford, and Dr. K. W. Allen, head of the Nuclear Physics Group of Aldermaston Atomic Weapons Establishment, as well as American authority Dr. Louis Rosen, of the University of California. Almost half of the total of 62 papers delivered were given by workers in the Australian National University. The conference coincided with the installation of the new tandem accelerator at the Australian National University.

NORA accepted

A NORWEGIAN proposal that her zero power reactor, NORA, should be used in a joint scientific research programme on reactor physics with the IAEA has been accepted. A trilateral contract has been arranged between the IAEA, Norway and the U.S.A. for the supply by the U.S.A. of a fuel core for the joint programme. This core will be enriched to 3 per cent. in the isotope uranium-235. Two other core loadings will be supplied by Norway, one consisting of natural uranium and one enriched to 1.7 per cent. in the isotope uranium-235. This is the first time the Agency has been able to participate in a fundamental scientific study of nuclear reactors.

100 kW JASON

EXPERIMENTS carried out recently by Hawker Siddeley on their JASON reactor at Langley have shown that this standard 10 kW reactor can operate intermittently at powers between 10 kW and 100 kW. The tests were designed to provide



LATINA

A general view of Latina nuclear power station in Italy. The administration block can be seen on the left, the turbine house in the centre and the reactor on the right. The station is being built by the Nuclear Power Group

information on the safety characteristics of reactors now in the design stage. Information was obtained on the effect of pump failure at 100 kW and the removal of decay heat by thermal convection of air, following the reactor scram (with water dumping) from full power. Three 20 min runs were made at 100 kW with cooling as for 10 kW. In two of the runs the coolant supply was completely interrupted so that reactor behaviour could be observed. No attempt was made to compensate for temperature rise, power fell quickly and the reactor stabilized at 10 kW. In the other run, cooling supply was constant at 4 gal/min. The reactor was scrammed from 100 kW and rapid removal of heat by air convection was observed.

Enriched uranium

AN ORDER to supply 20 per cent. enriched uranium for the 15 eMW high temperature gas-cooled pebble-bed reactor being constructed by Arbeitsgemeinschaft Versuchsreaktor (AVR) of Dusseldorf, Germany, has been given to the Mallinckrodt Nuclear Corporation of the U.S.A. The pebbles are made of graphite containing uranium-carbide in the centre as the fuel material. Mallinckrodt Corporation are supplying 325.6 lb of 20 per cent. enriched uranium (U-235) for this purpose. Construction work has already begun on the reactor and criticality should be achieved in 1963. Total cost of the reactor is estimated at 40m. DM, 50 per cent. of which will be borne by the German Government and 50 per cent. by private industry. The Mallinckrodt fuel will be made available under the "Atoms for Peace" programme through a bilateral agreement between the U.S.A. and Germany.

Symposium on criticality

CRITICALITY control in chemical and metallurgical plant is the subject of an international symposium organized by the OEEC European Nuclear Energy Agency in collaboration with Kernreaktor Bau-und Betriebsgesellschaft mbH from May 2nd to 5th, 1961, at the Karlsruhe Nuclear Research Centre in Germany. The symposium is intended for experts concerned with the criticality aspects of the design and operation of installations dealing with enriched uranium or plutonium, such as fuel element fabrication plant, reprocessing plant, conversion plant for enriched uranium or scrap recovery plant. Twenty lectures will be given by leading European and American specialists, together with discussions on both fundamental principles and practical applications of criticality control.

Research continued

A CONTRACT has been awarded to Tracerlab by the U.S. Army Laboratories at Fort Belvoir to continue research in the use of X-ray "Rayleigh Scattering" phenomena for particular military applications. This research is based on the theories of Lord Rayleigh on the interaction of solar light with atmospheric particles. It is hoped that by extending these concepts to the interaction of X-radiation with matter, instruments can be developed which will be capable of non-destructive inspection of reactor fuel rods and of detecting very small quantities of contaminants in process streams.

Harwell course

LECTURES, practical work, demonstrations and visits will all be included in the Fourth Advanced Course in "The Principles of Radiation Protection" to be held in the Harwell Reactor School from April 19th to July 18th, 1961. This course is intended for graduates working in the field of radiological health and safety. A wide field of background knowledge will be covered and principles rather than particular techniques will be dealt with. The academic standard set is high but the course will start with first principles and no previous specialized knowledge will be required. Lecturers will be drawn from the staff of the school, Harwell itself and other UKAEA establishments. Additional lecturers may come from outside bodies such as the CEGB, the Institute of Cancer Research and the Agricultural Research Council. Altogether there will be about 110 lectures in the theoretical part of the course, which will be divided into three main sections—basic scientific principles; principles of radiation protection; and general topics. The first of these will consist of about 48 lectures on such subjects as physics, human biology and choice of maximum permissible levels; the second will consist of about 25 lectures on units and measurement, principles of protection, criticality, monitoring, dispersion and protection of workers, and waste disposal; the third will consist of about 10 lectures, including a survey of the industry and the organization of the protection services and collaboration with the medical services, the uses of radioactive materials by outside bodies especially in medicine and industry, and legal considerations.

ISOTOPE WORLD

Radioisotopes in modern agricultural research

TWO research economic scientists, A. G. Homan and R. R. Tarrice, of Standard Research Institute, the non-profit-making scientific research establishment in California, have recently carried out a series of fundamental investigations into the present and future importance of radioisotopes in agriculture. The investigation has been carried out for the U.S. Atomic Energy Commission.

The American scientists contacted major centres of private and governmental agricultural research and evaluating institutions and organizations; they also interviewed outstanding scientists in their own particular field connected with agriculture.

According to the findings of the scientists, radioisotope research, though representing only 4 per cent. of the total agricultural research effort, should lead in the United States to a minimum of $180m. in added productivity each year for the next 20 years.

Insect Control

A large portion of the increased productivity in agriculture will come from improved insect control. At present, insects cause a $4 billion loss in American agriculture each year. Research using radioisotopes, aimed at a better understanding of the physiology and behaviour of insects, will contribute to development of control methods.

A good example was the recent experience of scientists in Florida who were attempting to control a local blowfly, the screw-worm larvae of which caused heavy losses to that state's cattle industry. They captured great numbers of the male flies, sterilized them by radiation, and then released them to perform fruitless matings. After only a few fly generations, the pest had all but disappeared, and Florida cattle breeders have saved $20m. annually.

Radioisotopes are also being utilized to study the processes of absorption, distribution, metabolism and elimination of insecticides within insects. These studies have helped to develop more effective insecticides and have helped explain how insects become resistant to insecticide.

Radioactive elements

Along the same lines, the radioactive elements have proved useful in the detection of minute residual amounts of insecticides in food and forage crops. The importance of this work can be appreciated when one realizes that 300m. lb of toxic insecticides are put on United States crops annually.

Some years ago, geneticists found that radiation could cause mutations in genes, thereby producing new plant varieties. The technique was applied to create varieties that are disease-resistant, more amenable to mechanical harvesting, higher in food value, better adapted to climate, higher in per-acre yield, etc. From such research has come a higher-yield oat variety that is resistant to crown rust, a rye that has a greater degree of self-fertility, and a rice that has shorter straw and is resistant to certain diseases, to cite a few. In all, radiation-induced mutations have produced 60 different crop plants that have economical importance.

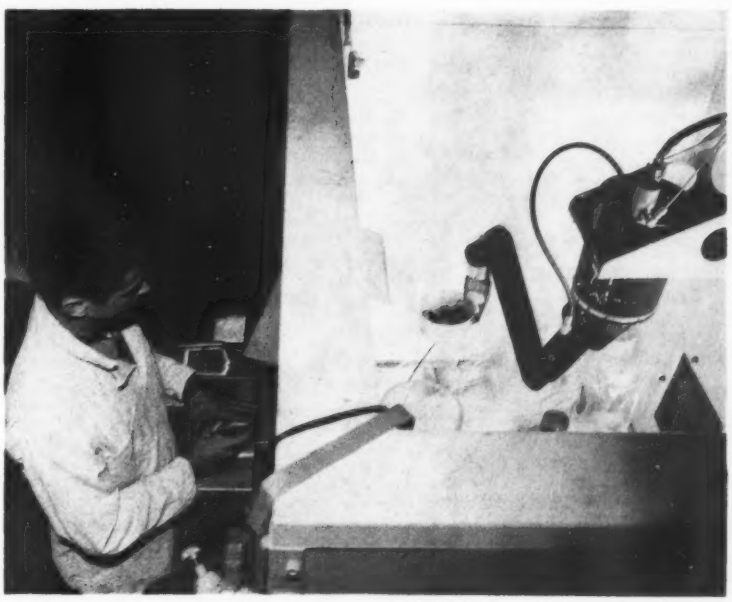
Plant physiology

Knowledge of plant physiology has grown tremendously as a result of radioisotope research. Among the examples noted by Homan and Tarrice was the information gained about the intake and usage of fertilizer by a plant. Radioisotope studies have provided data showing where fertilizers should be placed, what time in the growing cycle they should be applied, the age at which the plant absorbs the greatest quantity, and how much leaching or movement may take place in the soil.

Similar, physiological studies of potato plants have led to elimination of tip-burn in the plant's foliage, a defect that causes a 5-10 per cent. annual reduction in yield. Use of isotopes showed that tip-burn is a result of calcium deficiency in the leaf, a condition easily corrected.

Farm animals

In farm animal research, a technique may be perfected so that isotopes such as Ca45 and P32 can be used to determine skeletal physiology without having to sacrifice the experimental animals. The potential savings might then encourage more research into bone-building mechan-



Research technician of Standard Research Institute, California, using remote control apparatus for handling radioisotopes in various agricultural research projects

isms, uncovering knowledge that could be utilized in cattle production or even for the betterment of human health.

Fundamental studies of thyroid function using I131 can check the influence of that gland on reproduction, egg laying, wool production, growth and fattening, etc. Thyroid research on turkeys and chickens could result in strains of birds with up to 20 per cent. greater feed utilization. Likewise, study of thyroid physiology in cattle, especially as regards gland function as related to the temperature of the environment, may lead to development of dairy cattle capable of better milk production during the summer months in southern states.

One of the greatest difficulties in achieving maximum use of radioisotopes is the current shortage of trained personnel.

Isotope instrumentation

THE BRAZILIAN GOVERNMENT has recently placed an order with Tracerlab Inc. of Massachusetts for radioisotope instrumentation for the new medical centre in Brazilia, the new capital of Brazil. This new medical centre is destined to be the most modern hospital in South America. Medical, research and diagnostic equipment is to be provided for the utilization of radioisotope tracer techniques. Instrumentation will include electronic isotope apparatus for automatic analysis of medical and biological specimens and an isotope scanning system which allows doctors to positively, accurately, and quickly locate tumours or malfunctioning organs without resorting to exploratory surgery or costly, complicated diagnostic techniques.

IAEA Trombay Symposium

THE TASK of reducing agricultural insect pests has become most important in man's fight against hunger and in his efforts to raise living standards in many parts of the world. Radioisotopes and radiation offer new tools for reducing the enormous losses in food, textile fibre crops and animal produce which amount to many millions of pounds/year. For this reason IAEA recently organized at the invitation of the Indian Government, a symposium on Radioisotopes and Radiation in Entomology at Trombay, Bombay.

Papers were presented by experts from many member states which dealt mainly with radiation effects on insects (sterilization and lethal effects) and the use of radioisotopes for the study of the life and habits of insects including their metabolism and physiology; the use of radioisotopes in insecticide research and the public health problems involved in the use of chemical insecticides.

Chemical insecticides are at present the main weapons for combatting insect pests in agriculture, animal husbandry and forestry. Radioisotopes can serve to render the application of insecticides more effective and to prevent hazards to man, animals and crops resulting from their use.

By "labelling" insecticides with radioisotopes it becomes possible to trace their course within the insect at different stages of its life, and to study why they have toxic effects on certain species and why resistance to specific insecticides occurs or develops in others.

In view of the harmful effects to man of some insecticides it is essential to establish whether they eventually reach him through his food and in what quantities. Radioisotopes introduced into such chemicals as tracers provide particularly sensitive methods for establishing, both qualitatively and quantitatively, residues of insecticides on human or animal feeding stuff. These investigations may eventually lead to the establishment of international safety regulations for the use of different insecticides.

Feeding insects with radioactive food reveals their living, breeding and migration habits

Irradiation may serve to kill pests or, and this is the more promising method, to eradicate them by impairing their fertility.

On the other hand, radioisotopes may also lead to fuller knowledge about parasites which live on pests and destroy them. It might even be possible to increase the virulence of some of these useful parasites by irradiation.

(*Abstracts on page 177*)

Living Coral Studies

THERE is one major obstacle to the study of the growth of corals. This is the difficulty of keeping corals alive and healthy in laboratory aquaria for sufficient time for accurate growth-measurements to be made. Such experiments take weeks or even months. A more rapid method has been developed over the last four years using radioactive Ca45 as a tracer. Corals are unable to distinguish between the stable and radioactive varieties of calcium; both isotopes are deposited into the skeleton in the same ratio as they are present in the medium. The amount of radioactivity taken up under various controlled experimental conditions is therefore an index of growth and physiological function. This technique is so sensitive that growth can be measured in corals that have been exposed to Ca45 for only a few hours, and it can be adapted to the study of coral growth in the actual reef. As only small samples are needed for analysis it is possible to measure differences in the growth rate in various parts of a single colony or even within a single corallite. Although many basic questions of coral skeletogenesis remain to be answered, the use of these new techniques has at least made it possible to describe some of the factors that control and influence the calcification reaction. (*By courtesy of* Endeavour.)

Iodine-132 or Tellurium-132

ON RECEIVING an order for iodine-132 the Radiochemical Centre at Amersham promptly dispatches tellurium-132. This is not due to bad management but to the very rapid disintegration rate of I132. In fact the half-life of this substance is only 2 hr 20 min, which is, of course, far too little to deliver a consignment to a hospital or research centre. To overcome this problem a substance must be used which disintegrates into I132, such a substance is Te132. The half-life of Te132 is a little over three days and it can be despatched in an easily handled form packed in a glass tube. The customer has only to pour a predetermined amount of a weak solution of ammonia through the tube to obtain the corresponding amount of I132 which has been forming during transit of the Te132. The tube can be repeatedly "milked" for iodine. Most of the applications of this material are in the study of thyroid disorders or their treatment. The thyroid has an exceptional faculty for accumulating iodine. Tellurium is obtained by subjecting uranium metal wire to an intense flux of neutrons in the BEPO reactor at Harwell. A certain proportion of the uranium atoms are split by the neutrons and produce Te132 as one of the fission products. At Amersham this wire is processed by remote control to extract the tellurium and prepare it for despatch.

"Radiometric Exchange"

A U.S. patent has been issued to Tracerlab, Inc., which involves the broad principle of "radiometric exchange," a technique with potential wide utility in air pollution studies, atmospheric and outer space measurements and industrial process control. Radiometric exchange involves the super-sensitive detection and analysis of chemicals and gases by causing them to react with a radioactive compound. Techniques using this new method offer several distinct advantages over previously existing techniques, these are: (*a*) extreme sensitivity with accuracy in the parts per billion range; (*b*) continuous monitoring and analysis for long periods of time without attending personnel; (*c*) simplicity and compactness, *i.e.*, in some cases the instrument need be no larger than a household flashlight; (*d*) selectivity—utilization of the method allows analysis of a single compound or gas in a situation where many others might also exist; (*e*) the system can detect an extremely wide range of compounds.

In a typical case, air pollution studies, the principle is applied to the measurement of sulphur dioxide in the atmosphere by drawing the atmosphere through a small reaction cell. The sulphur dioxide in the air reacts with the cell to form a radioactive gas. The amount of radioactive gas generated is directly proportional to the amount of sulphur dioxide in the air. By counting the radioactivity present with a Geiger counter, a direct determination of the sulphur dioxide content in the atmosphere is accomplished.

Isotope and radiation symposium in Bombay

The abstracts given below are taken from papers presented at a symposium on Radioisotopes and Radiation in Entomology which was organized recently by the International Atomic Energy Agency in Bombay

On the Role of Lethal Mutants in the Control of Populations, *R. C. von Borstel, University of Pavia, Pavia, Italy, and A. A. Buzzati-Traverso, Oak Ridge National Laboratory, Oak Ridge, Tennessee, U.S.A.*

POPULATION control by release of irradiated males requires that the sperm must be damaged by radiation. The type of damage induced by radiation imposes a restriction on which species may be controlled because if the sperm are functionally damaged by radiation, then for effective control, the females must be monogamous. If dominant lethality is induced in sperm then either polygamy or monogamy can prevail.

It is generally accepted that dominant lethal events are induced in sperm at doses much lower than those required to hamper sperm function or cause sperm inactivation. With *Drosophila* it is possible to test directly the influence of release of irradiated males into an artificial population where polygamy is the rule.

Preliminary experiments have been performed under conditions of unlimited production of offspring.

It appears that radiation induces dominant lethality in sperm, and the sperms that bear dominant lethals are able to compete successfully with normal sperms. A series of tests are currently under way to ascertain the degree of induced dominant lethality and sperm inactivation at different X-ray dosages.

Results of experiments are presented together with a general discussion of the possible use of dominant and recessive lethals for bringing about collapse of artificial and natural populations.

Studies on the Persistence, Decay and Distribution of Radiophosphorus in Grasshoppers and the Madeira Cockroach, *H. Huque, Pakistan Ministry of Food and Agriculture, Karachi, Pakistan.*

THREE species of grasshoppers and the Madeira Cockroach were labelled with P32 for persistence, decay and distribution studies.

The persistence of P32 in the grasshoppers and the Madeira roach was determined in measurable quantities beyond 30 days, while the biological half-life was found to range between 6.8 and 7 days in grasshoppers and 8.5 and 10 days in the Madeira roach.

Radiophosphorus when introduced in test insects in reasonable quantities showed no toxic (or detrimental) effects on any stage of development of the insects.

P32 was found in the cast skin and the oothecae of the Madeira roaches. Very small amounts of radioactivity were found in the egg capsules of the grasshoppers and nothing in their exuviae.

The distribution of P32 in both the insects (grasshoppers and the roach) was quite similar after 48 hours. The distribution study was also checked by radioautograph techniques. The radioautograph plates revealed that the concentration of the isotope was greatest in the region of the hind gut and the metathoracic legs.

The Scope of the Use of Radioisotopes and Radiation Sources in Entomology in Pakistan, *H. A. Qayyum, Punjab Agricultural College, Lyallpur, Pakistan.*

IN PAKISTAN, as in many other countries, there is a growing realization of the benefits which can be derived from the application of radioisotopes and radiation sources in different branches of agriculture. The complete eradication of the screw worm fly which was estimated to cost the cattle breeders in the United States of America $20m. each year has definitely given stimulus to the application of nuclear energy in the field of entomology.

In Pakistan work has so far not been taken up in this direction. But it is hoped that with the establishment of two Agricultural Research Centres at Lahore and Dacca by the middle of next year, the use of radioisotopes in entomological research and the eradication of insects to protect crops and farm animals will be started. Some of the problems which deserve the special attention of entomologists in Pakistan are the conditions required for effective use of insecticides and the possibility of using radioactive methods in toxicological studies on insects and rodents. At present there is a trend in Pakistan, as in many other countries, to concentrate upon the chemical control of different insects. For this purpose all the newly manufactured non-systemic and systemic insecticides are being brought into use. The use of radioisotopes can greatly assist the studies of the mode of action of all such insecticides, as, for instance, their penetration and decomposition in different organs and tissues of insects. In addition, similar radioactive techniques can be used to measure the time lag between the application of a lethal dose of an insecticide and its effects on insects and rodents.

The study of migratory habits of insects can also be made effective and efficient with the help of radioisotopes.

It would be of particular interest if radiation sources could be used to control crop borers, fruit flies and stored grain pests.

The Future of Radioisotopes in Insect Control Investigations in the Philippines, *G. B. Viado, Philippine Atomic Energy Commission, National Science Development Board, Manila, Philippines.*

AGRICULTURE is the major industry in the Philippines, yet the production of the staple food and other basic necessities is very low and insufficient to meet the local demand. As a result, the country imports annually millions of pesos' worth of rice, corn and other agricultural products.

One of the major causes of low production of agricultural crops in the Philippines is the enormous damage caused by insect pests on both the standing crop and the stored product. It is estimated that about 15 per cent. of the produce is lost due to insects.

Not a single insect pest affecting Philippine agriculture has been thoroughly studied. The greatest bulk of investigations on insect pests in this country is on life-history, morphology, host survey, and control. Control measures employed at present, particularly the use of chemicals, are based mainly on results of investigations in foreign countries, which may be the cause of protection being ineffective so far. Much essential information regarding pests, particularly those on their ecology, is needed. The difficulties of undertaking investigations on ecology of insects in this country, prior to the advent of radioisotopes, are mainly responsible for the almost complete lack of knowledge in this field.

The use of insecticides in insect control in the Philippines is limited not only by inadequate information on the bionomics of the pests but also by the toxicity of these chemicals to humans. Detection and assay of insecticide residues on treated foodstuffs with the use of tagged insecticides will enable the formulation of effective control measures in order to protect the consumer.

In the light of present knowledge, the use of radiation for the control of insects affecting Philippine agriculture can be investigated. In the Philippines, shelled corn, clean rice, mungo, and other foodstuffs cannot be stored longer than three months without extensive damage by stored-product insects. The use of radiation-sterilized males as a possible means of control in this country can also be investigated.

Biosynthesis of the Constituent Amino Acids of the Silkprotein in the Silkworm Larva, *T. Fukuda, Sericultural Experiment Station, Tokyo, Japan.*

THE current study was carried out using radioactive C14 to elucidate the mechanism of the biosynthesis of glycine, alanine, serine, tyrosine,

etc., which are the constituent amino acids of the silkprotein.

A certain amount of the compound labelled with C14 was given *per os* to the silkworm at the fifth stage, and then these silkworms were reared on mulberry leaves until they produced their cocoons. From the acid hydrolysate of the radioactive cocoon fibres amino acids were isolated respectively to measure their radioactivities. The isolated amino acids were also degraded stepwise to elucidate the C14 distribution in the amino acid molecule. C14-compounds were added to the enzyme solution obtained from the silkworm tissues and then the mixture was incubated. The amino acid synthesized newly was identified by paper chromatography, radioautography, etc.

The results obtained using the C14-compounds were as follows: (i) Conversion of serine to glycine; (ii) Formation of glycine from glucose; (iii) Conversion of pyruvate to glycine; (iv) Formation of alanine by transaminase from pyruvate; (v) Conversion of glycine to serine; (vi) Conversion of pyruvate to serine; (vii) Conversion of phenylalanine to tyrosine; (viii) Formation of α-ketoglutaric acid, oxalacetic acid and glyoxylic acid from glucose.

All the mechanisms of the biosynthesis of amino acids in the silkworm larva are discussed, which includes also results obtained from experiments without radioisotopes.

Difference in the Fate of Methyl Parathion Between Both Sexes of the American Cockroach, *C. Tomizawa, National Institute of Agricultural Sciences, Tokyo, Japan.*

FATE and behaviour of P32-labelled or S35-labelled methyl parathion applied topically on the American cockroach were compared between both sexes of the insect. In the experiment with P32-labelled methyl parathion, radioactive material rapidly accumulated in the digestive tract of the insect, especially in the foregut, at the agitation stage. The material moved from the foregut to the midgut and hindgut with the advance of poisoning. When the same dosage was applied on both sexes, females absorbed larger amounts of methyl parathion than males.

Accumulation of radioactive material in the nerve cord and brain was smaller in females than in males, and a larger transfer of radioactive material into the digestive tract was observed in surviving females than in dead females. The accumulation rate of radioactive material in each part of the digestive tract was different between P32-labelled and S35-labelled methyl parathion. S35-labelled material accumulated not only in the foregut, but also in the midgut and hindgut, at the agitation stage.

Preliminary Studies on the Effects of Gamma Radiations on the House-fly Pupae with Special Reference to the Critical Periods in Relation to the Mechanism of Emergence, *K. Nair, Atomic Energy Establishment, Trombay, Bombay, India.*

WITH special reference to the mechanism of emergence, studies on radiation sensitivity of the house-fly pupae of different stages of development have been carried out. The different dose levels employed were 500 r, 1,000 r, 2,000 r, 2,500 r, 5,000 r and 10,000 r. The data obtained on the per cent. emergence in each group indicated that the early stages of development were most sensitive to radiation since a dose of 2,000 r and above applied to 5-hour-old pupae resulted in no emergence at all, while the same doses applied to 30-hour—80-hour-old pupae did not appreciably affect the mechanism of emergence in these groups. Moreover, it was also observed that in the case of the 2-hour and 5-hour old irradiated pupae development was complete, but the flies failed to emerge.

Radioactive Tracer Techniques in Insect Biochemistry, *S. P. W. Winteringham, Agricultural Research Council, Pest Infestation Laboratory, Slough, U.K.*

RADIOACTIVE tracer techniques combined with microfractionation techniques such as paper chromatography have provided powerful tools for studying the biochemical problems of insect control by chemicals.

An important aspect of this type of work is the separation, assay and identification of labelled compounds recovered in trace amounts from insect tissues. Automatic radiochromatographic techniques are available and identification may be established by co-chromatography with authentic compounds, and by studying the action of chemical reagents and specific enzymes on the labelled fraction.

A serious threat to progress in the chemical control of agricultural pests is the increasing numbers of insects which display such high levels of resistance to the established insecticides that their use has had to be abandoned. Labelled insecticides have been extensively used for comparing their absorption, metabolism and excretion by normal and insecticide-resistant insects. The use of labelled dieldrin and its chemical relatives in this way has provided essential data on the mechanisms of resistance. The evidence to date strongly suggests that resistance to dieldrin in *Diptera* is not due to detoxication or failure of the insecticide to penetrate the insect cuticle.

By labelling pools of related metabolites *in vivo* the effects of insecticides upon the insect may be studied. Labelled pools are formed *in vivo* by feeding or injecting insects with suitable labelled compounds.

Comparison of the labelled pools formed when (2-C14) acetate and (P32) PO_4^{3-} were injected into adult insects provided valuable data on the biochemistry of insect nerve and muscle. For example, the significance of *L*-α-glycerophosphate in the carbohydrate metabolism of the flight muscle has been demonstrated, and studies made of the kinetics of acetylcholine metabolism in the nervous tissue of the intact insect.

Pools of metabolites labelled with C14 or P32 have been used for studying the mode of action of dieldrin and other insecticides in the insect. Thus, the organic-phosphorus insecticides appear to slow the rate of acetylcholine synthesis *in vivo* although they are without effect on the corresponding enzyme systems *in vitro*.

Caution must be exercised in the interpretation of tracer experiments applied to the problems of insect resistance. For example, a difference between the metabolism or excretion of a labelled insecticide by susceptible and resistant insects may not explain resistance but simply be a consequence of susceptibility.

Radioisotopes and the Insect Central Nervous System, *J. E. Treherne, Agricultural Research Council, Unit of Insect Physiology, Department of Zoology, Cambridge, U.K.*

THE USE of radioisotopes has facilitated research at Cambridge on the physiology of the insect central nervous system. In particular this work has been concerned with the influx of various radioactive compounds through the continuous cellular and fibrous membrane which envelopes the nervous system. It is currently believed that this structure, the perilemma, functions as a diffusion barrier restricting the entry of such substances as sodium and potassium ions and acetycholine into the underlying nervous tissue. On the other hand this structure must also, as Wigglesworth has pointed out, be specialized to allow adequate exchanges of nutritive substances to take place between the central nervous system and the haemolymph. This important role has been little studied and an attempt has been made to understand these processes by studying the uptake of C14-labelled molecules in the abdominal nerve cord of the cockroach. At the same time the opportunity has been taken to learn something of the biochemical events in insect nervous tissue by following the metabolism of some labelled compounds in the nerve cord of this insect. It is anticipated that this information may help to throw some light on the entry and subsequent behaviour of insecticide molecules in the insect central nervous system. These findings are discussed in relation to current concepts of the physiology of the vertebrate nervous system.

Radioisotopes in Ecological and Biological Studies of Agricultural Insects, *D. Jenkins, United States Army Chemical Corps Biological Laboratories, Fort Detrick, Maryland, U.S.A.*

ATOMIC ENERGY used for research and control of agricultural and livestock insect pests has proven to be of very great value. Radioisotopes are an excellent tool in carrying out detailed and accurate ecological studies of insect pests required for effective control. With this information, economic control of insects can be carried out by hitting the weakest links and most vulnerable points using crop practices, quarantines, killing or sterilizing techniques, and other control methods on a co-ordinated basis.

Radioisotopes have been of value in labelling and studying the dispersal and movement, life history, and behaviour of, underground insects, orchard and forest insects, honey bees, and cotton and food crop insects. They have been helpful in elucidating the role of plant sucking insects particularly with regard to plant virus transmission. Ecological studies have been carried out on radioisotope-tagged flies, ticks, mosquitoes and other insects which transmit diseases or are important pests of cattle and other domestic animals. Use of radioisotopes has contributed to the study of parasites and predators of agricultural and livestock pests and disease vectors. They have been of value in ecological studies on food chains, nutrition cycles, and population studies.

New and additional biological studies are suggested using radioisotopes and radiation. Certain plant-insect relationships can be explored using radioisotopes, for example in studying trace elements which sometimes form the basis of plant resistance to insect attack. They can be used in studying pollination of plants by insects. Domestic animal host and insect parasite relationships can be studied using radioactivity to elucidate life histories and to locate the radioactive parasites in the host animals at intervals of time. Radioactivity can be used to locate egg laying and overwintering sites of various insects. Radioisotopes and radiation provide excellent tools in research providing ecological data required in successful control by co-ordinated use of irradiation and sterilization, insecticides, special chemicals and hormones, new genetic developments including abnormal sex ratio and sterility producing genes, and natural control with parasites and predators.

Effect of Radiation on Mexican Fruit Fly Eggs and Larvae in Grapefruit, *L. Brownell and M. Yudelovitch, University of Michigan, Ann Arbor, Michigan, U.S.A.*

A LIMITED STUDY has been made of the effect of gamma radiation from Co60 on the eggs and larvae of the

Mexican fruit fly. Various doses from 5,000 to 90,000 rad were given to fruits one and twelve days after infestation to explore the effects of irradiation on the egg and first instar larvae stage. Fruits containing full grown larvae and larvae at intermediate stages were also irradiated with similar doses. Frequent examination and dissection of the fruits were used to determine larvae mortality, larval damage to fruits, presence of pupae and presence of adult flies.

Dissected fruits given radiation doses of 5,000 rad or more during the egg or first instar larvae stage showed no presence of insects and no trace of insect damage. Fruit infested with adult larvae produced numerous pupae recoveries but no adult flies emerged from pupae recovered from fruits receiving a radiation dose of 5,000 rad or more. The conclusion is made that a gamma radiation dose of 5,000 rad (and possibly less, based on limited tests of 2,000 rad) will break the life cycle of the Mexican fruit fly although the larvae stage may survive appreciably greater dosages.

A design for a railway mobile gamma irradiator for treating infested fruit is proposed.

The Use of Radiation Sources for Insect Control, *T. Horne and L. E. Brownell, Curtiss-Wright Corporation, Princeton, New Jersey, and University of Michigan, Ann Arbor, Michigan, U.S.A.*

THE different radioisotopes and electrical machine sources of radiation are briefly discussed, but a greater emphasis is placed in radioisotopes because of their greater reliability and ease of operation. The numbers of curies of the most suitable isotopes for various applications are tabulated. The general principles of source design covering radiation flux intensity, optimum dose distribution and shielding requirements are outlined. Various procedures for the use of radiation in control of insect populations are reviewed, including the sterile male release technique, direct irradiation of agricultural products, the combined use of insecticides with irradiation and the possible use of radiation as an insect repellent. Possible new applications are suggested, *e.g.*, the combined use of insecticide and sterile male release in a programme for the eradication of the malarian mosquito in the Indonesian islands.

A new method is put forward for storing grain for a long time without the need for periodic fumigation. This method involves the use of a special grain container and radiation processing. Designs for various irradiators and some of the problems encountered are reviewed.

Special reference is made to small semi-portable irradiators suitable for insect sterilization; to a flexible laboratory irradiation unit covering both research and field scale applications, and to some of the large production scale facilities which have been proposed for commercial use.

In view of the proven effect of radiation for insect control, it is urged that the health authorities give serious consideration to this technique for reducing losses in the world's food supply.

Metabolism of Insecticides by Plants, *J. E. Casida, University of Wisconsin, Madison, Wisconsin, U.S.A.*

THE STUDIES on the metabolism of inorganic, botanical and chlorinated hydrocarbon insecticides in plants have generally been made without the use of radioisotopes. It is only with the organophosphates that radiolabelled compounds have been fully, and even dramatically, utilized. These radiotracer studies have been a major factor in the rapid development of the background knowledge essential to the safe use of systematic insecticides.

The current knowledge of the metabolic fate of insecticides in plants are reviewed with particular attention to the synthetic routes available for labelling organophosphates with P32 and the use of these compounds in metabolism studies.

Radioisotope Techniques and Recent Research on Metabolism of Insecticides in Insects, *T. L. Hopkins, Kansas State University, Manhattan, Kansas, U.S.A.*

INSECTICIDE metabolism, which is only a part of the complexity of interaction between insect and chemical, reflects the defensive mechanisms of the organism and sometimes yields clues as to the mode of intoxication. An understanding of these processes can aid in the search for more specific control agents and solutions to the enormous problem of insect resistance to insecticides. Radiotracer techniques combined with micromethods of chemical separation such as paper chromatography are ideally suited for elucidating the fate of insecticides applied to insects.

This paper briefly reviews techniques useful for investigations of radiolabelled insecticides and insects and their application to the study of insect mechanisms of resistance. Data are presented on the quantitative fate and metabolism of P32-labelled *Dipterex*, *O,O*-dimethyl 1-hydroxy-2,2,2-trichloroethyl phosphonate, in normal and *Dipterex*-resistant houseflies. The resistant fly strain was able to detoxify the insecticide and excrete the water-soluble metabolites at a more rapid rate than the normal flies. Metabolites were identified by paper chromatography and no qualitative differences were found between strains.

Research on Radioisotopes and Radiation in Insect Control, *D. Woidhaas, U.S. Department of Agriculture, Orlando, Florida, U.S.A.*

A SUMMARY of the development and application of the sterile male release technique, in which gamma radiation was used as the sterilant, in the eradication of the screw worm, is presented. Preliminary laboratory and field results on the application of this same technique to the control or eradication of mosquitoes and fruit flies are also presented. Results are given showing the lethal effects of radiation of some insects of medical importance including the body louse, house fly, American cockroach, firebrat, bed bug and Pharaoh ant.

Research work on the metabolism of radiolabelled systemic insecticides in animals is summarized, giving details on experimental design and important results. Also included are studies using radioisotopes to aid research on the mode of action of insecticides and repellents, metabolism of insect repellents, and insecticide resistance problems.

Problems in Measuring Radioisotopes Used as Tracers for Vital Functions in Insects, *W. Kloft, University of Wurzburg, Wurzburg, Germany.*

IN studying metabolism-reactions or the transport of substances in insects by radiation measured from the outside, you must take into account many factors which influence the result. Of especial importance are the absorption and the back-scattering in the relatively thin and also inhomogeneous tissue-layers of the insects.

A direct method for determination of the absorption coefficient for β-radiation of various types of tissue will be specified. In addition to this it is necessary to take off the exterior tissue layers which have to be examined. The change of intensity of radiation that is caused by this procedure can then be examined. By an indirect method the former rate of impulses is re-established by interposition of aluminium-foils of known thickness in mg/sq.cm. The data of the suitable absorption filters for substitution will be transferred to the tissues. After detection of the absorption coefficient for the tissues (especially the cuticula) of the used insect species and stages, it is possible to find out a correction factor for calculating the real activity from the measured rate. In a similar way the back-scattering, especially at the cuticula is taken into account for quantitative measurements. Other problems of measurement, as for example, the apparent increase of activity by cuticular excretion on the whole surface are discussed. This cuticular excretion results in a higher counting rate because part of the radioactivity is on the surface so that radiation from it is not reduced by absorption.

Experiments for Incorporation (Assimilation) and Excretion of Marked Substances in Aphids, *W. Kloft and P. Ehrhardt, University of Wurzburg, Wurzburg, Germany.*

APHIDS are plant-sucking insects with a relatively high metabolism and are therefore well qualified for studying the incorporation and excretion of marked substances. A particular advantage is the uptake, nearly free of contamination, of radioactive compounds from marked plants through the stinging and sucking mouth-parts. The measurements show that the insects take in food only some time after stinging, at a moment which corresponds with reaching the phloem. Then the activity suddenly increases to an approximate maximum, which is reached after filling the intestinal tract with marked phloem-sap. The activity, however, increases slowly because of resorption from the midgut.

In the meantime incorporation (assimilation) and excretion of the radioisotopes begins in different ways. Of special interest is their incorporation into the saliva and the following re-injection into the plant. The period of uptake of the tracer from a plant to the re-excretion with the saliva is five hours at a temperature of 22-24 C. This time period, as well as the exact course of excretion of saliva during sucking and the distribution of saliva in the plant sucked by the insects, have been analysed exactly because of their great importance for the physiology of nutrition and the phytopathological effects of the aphids.

These tracer-experiments are model experiments for the problem of the transmission of virus (especially persistent ones) by plant-sucking insects. The further excretion of the radioisotopes takes place with the honeydew as well as by the bearing of living young larvae. The first of these young-born larvae have only a low activity which increases after longer periods of resorption in the maternal organism. By using P32 a registration of the phosphate-metabolism of the ovary in the live aphid is possible, because of the continuing ovoviviparie. By measuring all these kinds of excretion as well as the remaining activity we can find out the biological half-life period and the amount of actually assimilated tracers. The circulating part will be registered by separate measuring of the haemolymph. Constant

temperature is preconditioned, because the processes are highly influenced by changes in temperature.

A Study of the Phospholipids of Dieldrin Resistant and Susceptible Houseflies with Particular Reference to Those of the Thoracic Ganglion, *R. G. Bridges, H. D. Crone and J. R. Beard, Agricultural Research Council, Pest Infestation Laboratory, Slough, U.K.*

A STUDY of the phospholipids of the housefly has been made because of the possibility that some alteration in membrane structure or active transport is implicated in the mechanism of dieldrin-resistance in insects. The phospholipids of a dieldrin-resistant strain of housefly and a susceptible strain from which it has been derived have been labelled by feeding the flies on P32-labelled orthophosphate solution for 24 hours and then allowing them to metabolize the adsorbed P32-phosphate for periods up to 36 hours.

Thoracic ganglia have been removed and the phospholipids separated by chromatography on silicic acid impregnated paper strips. Four major phospholipid fractions can be separated which appear to be the same as those obtained from extracts of whole flies. In the case of whole fly extracts the identity of the fractions is as follows: fraction II phosphatidyl inositol, fraction III lysocepalin, fraction IV a mixture of phosphatidyl choline and an unidentified phospholipid, and fraction V phosphatidyl ethanolamine and phosphatidyl serine. Fraction I consists of non-phospholipid phosphorus containing compounds, Maximum labelling of the fractions was obtained after feeding the flies (on glucose and water) for one week after removal from the P32-phosphate.

The distribution of the P32-activity in the separated fractions from the ganglia of the resistant and susceptible fly showed no significant differences at the time of maximum labelling. There was, however, some evidence for a slower turnover of P32-activity into the two major phospholipid fractions (IV and V) from the resistant fly. This was made obvious when the flies were fed on milk in addition to glucose and water.

Preliminary studies on turnover for much shorter periods have been carried out on phospholipid extracts from whole flies injected with P32-labelled ortho-phosphate solution. These have shown a more rapid turnover of P32-activity into the phosphatidyl inositol fraction (II) in the case of the resistant flies although in these short-term experiments there seems to be no difference in turnover into fractions IV and V from the two strains. The possible significance of the findings is discussed.

The Effects of Continuous and Fractionated Doses of Gamma Radiation on the Survival and Fertility of the Grain Weevil, *D. Jefferies, Wantage Research Laboratory, Wantage, U.K.*

CALCULATIONS have shown that many megacuries of Co60 are required to disinfest grain at 16,500 rep, the dose level evaluated for commercial treatment, at 200 ton/hr, the minimal handling rate demanded by the trade. Maximum efficiency in the use of radiation plant might be obtained with sources of lower curie strength to ensure continuous operation if the full dose for sterilization could be given in a process of repeated passes. The question arises as to whether many sub-lethal and sub-sterilizing doses will provide the same measure of control as continuous treatment.

Accordingly, an investigation was made into the effect of dose fractionation on the radiation susceptibility of the grain weevil. Comparison of fractionated and continuous treatment showed differences in survival and fertility which may be attributed to "recovery" of somatic and reproductive cells during the intervals between treatment.

Differences in survival were obtained in all developmental stages, being particularly marked in pupae; recovery was obtained with intervals of 10 minutes and longer, the process being governed by the number of fractions, fractionated dose and interval temperature. Recovery in reproductive capacity was obtained in irradiated eggs, larvae, pupae but not adults. Whilst these effects are manifest at low doses, fractionated treatment does not adversely affect the degree of control achieved at the commercial dose level.

Some Recent Studies, Involving the Use of Radioisotopes, of the Feeding Behaviour of Two Phytophagous Insects, *C. J. Banks, Rothamsted Experimental Station, Harpenden, U.K.*

THREE examples from the author's researches on insect pests illustrate the solution, with radioisotopes, of problems which could not readily be solved in other ways.

The feeding and excretion rates of *Aphis fabae* Scop. were estimated by allowing the insects to feed on bean leaves made radioactive with P32 and then relating the radioactivity of the aphids to that of the leaves. The results are presented and the method criticized.

By allowing groups of *A. fabae* to feed on bean plants made radioactive with P32, the hypothesis that ant-attendance significantly increases the aphid's feeding and excretion rates was confirmed.

The movements and feeding behaviour in the field of adult Senn (*Eurygaster integriceps, Put.*) were studied in Iran by tagging individual insects with small pieces of Ta182 so that they could be detected from a distance with a suitable instrument. The results are described.

Tyrosine Metabolism and Cuticle Sclerotization, *W. Laufer, K. E. Sekeris and P. Karlson, University of Munich, Munich, Germany.*

THE so-called "sclerotization"—tanning and hardening of cuticles—is the main process underlying the Puparium formation in flies, *e.g., Calliphora erythrocephala.* It is generally assumed that the tanning is due to o-quinones arising from tyrosine by the action of an enzyme, phenoloxidase. The tyrosine metabolism and the incorporation of various radioactive substances related to tyrosine into the cuticle during sclerotization has been studied.

It has been demonstrated, with uniformly labelled tyrosine, that about 80 per cent. of the free tyrosine enters the cuticle. Reductive hydrolysis of the cuticle yields active o-dihydroxyphenolic substances. Radioactive tyrosine was not present. Protein synthesis could be excluded, for leucin (1-C14) shows only minor incorporation.

Besides uniformly labelled tyrosine, tyrosine (β-C14) and 3.4.-dihydroxphenylalanine (β-C14) are incorporated, but not hydroquinone (2, 3, 5, 6-C14).

The first step is the oxidation of tyrosine to DOPA, for DOPA is incorporated to a greater extent than tyrosine. The second step should involve the α-amino group (otherwise the reaction would turn to melanin formation). There are two possibilities, deamination or acetylation. From the larvae of *Calliphora erythrocephala*, N-acetyldopamine was isolated.

It is present only in the larval stage. In the pupae it is transformed to the O-o-glucoside. This glucoside is to be found in small quantities and only in 5-6 day old last stage larvae, the amount gradually increasing, reaching a maximum during puparium formation. N-acetyldopamine was shown to be incorporated in the cuticle of the larvae during sclerotization, using radioactive(C14) N-acetyldopamine.

C136-Dieldrin in Mice, *D. Heath, Medical Research Council Laboratories, Carshalton, U.K.*

THE distribution of C136-Dieldrin injected intravenously into mice (L.A.C. grey strain) was studied. Extraction of C136-Dieldrin from tissues proved difficult, and the methods used are described in detail.

Shortly after injection high concentrations were found in the liver and brain, but the compound rapidly dispersed, and 24 hours after injection was mainly in the fatty tissues. Very little was excreted. Some was probably metabolized. An attempt is made to relate these findings to the toxic effects.

The Use of Radioisotopes and Radiation in the Field of Plant Protection, *S. V. Andreev, All-Union Research Institute for Plant Protection, Leningrad, U.S.S.R.*

EXTENSIVE investigations are being carried out in the Soviet Union with a view to working out methods for using radioisotopes and ionizing radiation for the solution of theoretical problems and the carrying out of practical work in the field of plant protection.

Ionizing radiation is used for its effects on micro-organisms, crop seeds and insects.

By means of the effects of ionizing radiation on micro-organisms we have produced strains of entomopathological fungi with increased virulence.

Sterilizing doses for stored-products pests have been worked out and used as the basis for the design of a gamma de-insector.

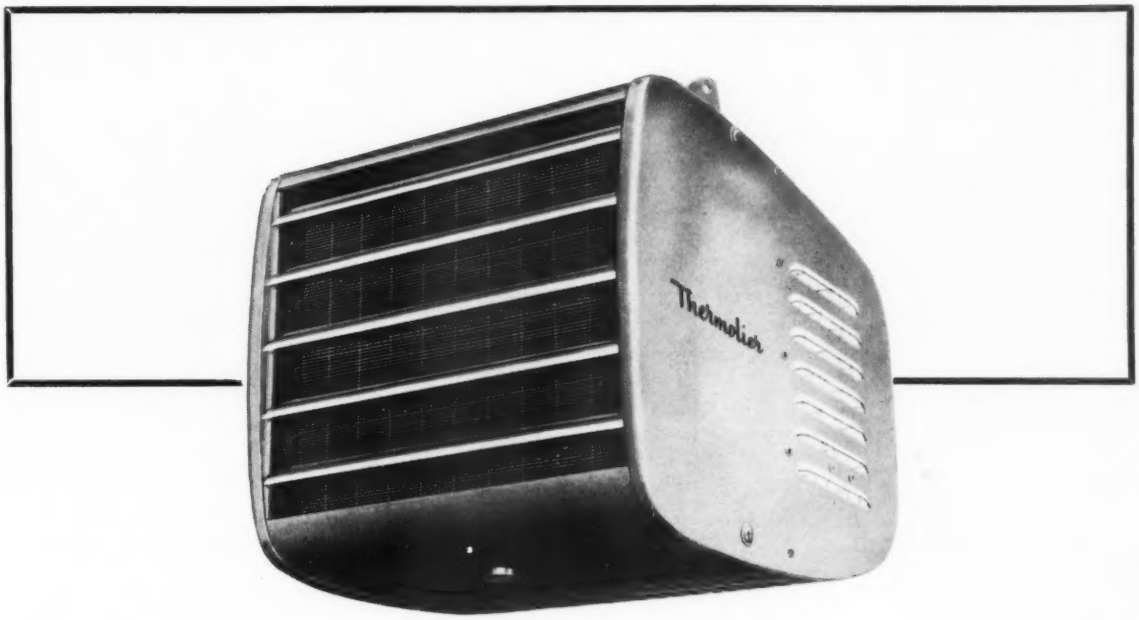
The use of isotopes as tracers has made it possible to follow the dynamics of the movement of insecticides within plants and within the organisms of pests; to make a comparative evaluation of toxic agents having a systemic action; and to ascertain the duration of the toxic characteristics of such agents in plants and agricultural produce, which is very important for defining the safe time-limits for using toxic agents on agricultural crops.

For studying the selective action of the 2,4-D herbicides, the concentrations of herbicides as governed by additions of mineral oils were determined.

The labelling of toxic chemicals with short-lived isotopes makes it possible to test the degree of effectiveness, for various crops, of airborne and ground techniques of dusting and spraying and also to ascertain the required amount of toxic chemicals per unit of area in relation to the crop grown, and to determine the effectiveness of various systems of dusting and spraying.

The method of marking agricultural pests with radioisotopes makes it possible to study the migration of large-scale grain-crop pests and their parasites, to define the reservoir areas, the size of the populations, etc. The method also makes it possible to study the food cycles, to locate predatoriness and parasitism among insects, and also the preferences of predatory and parasitic insects with regard to their victims and hosts.

Further advances along the lines described will hasten the solution of urgent problems connected with plant protection.



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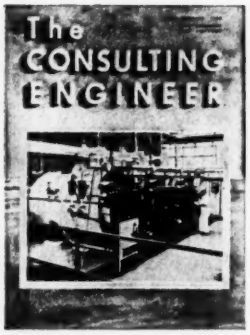

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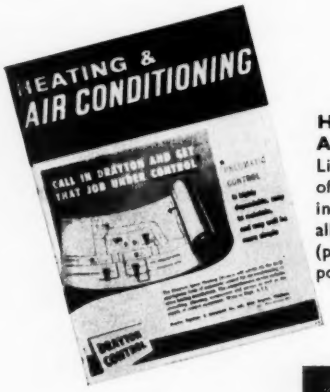

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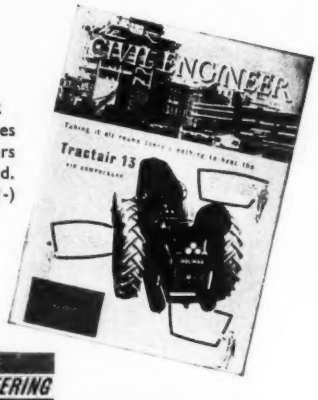

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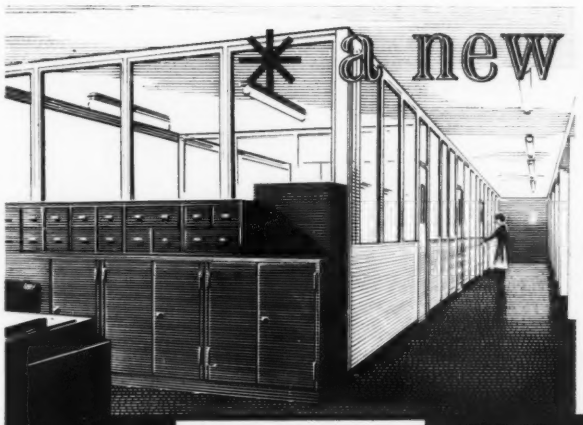

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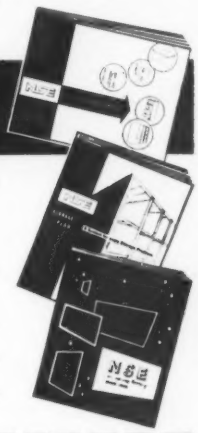

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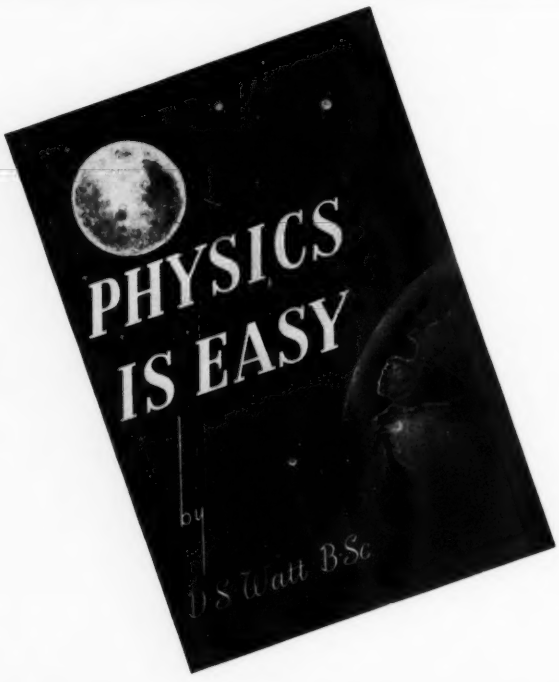

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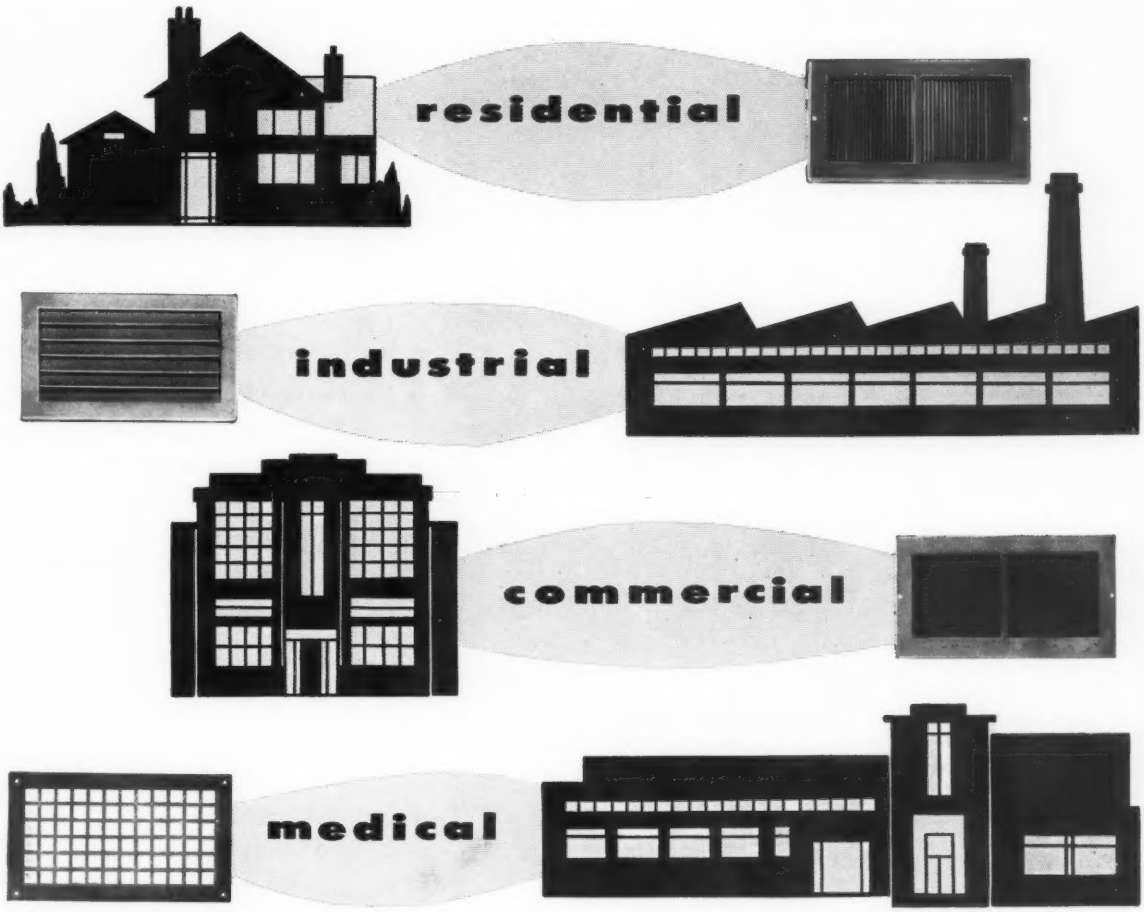

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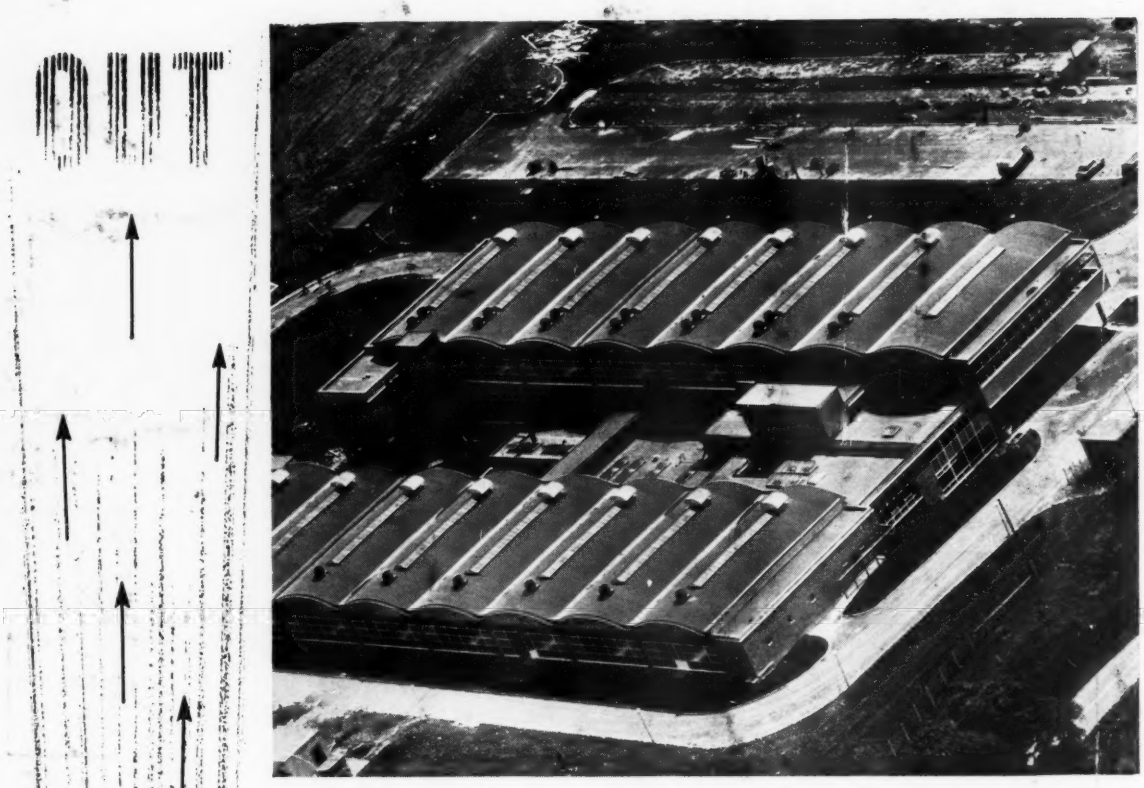

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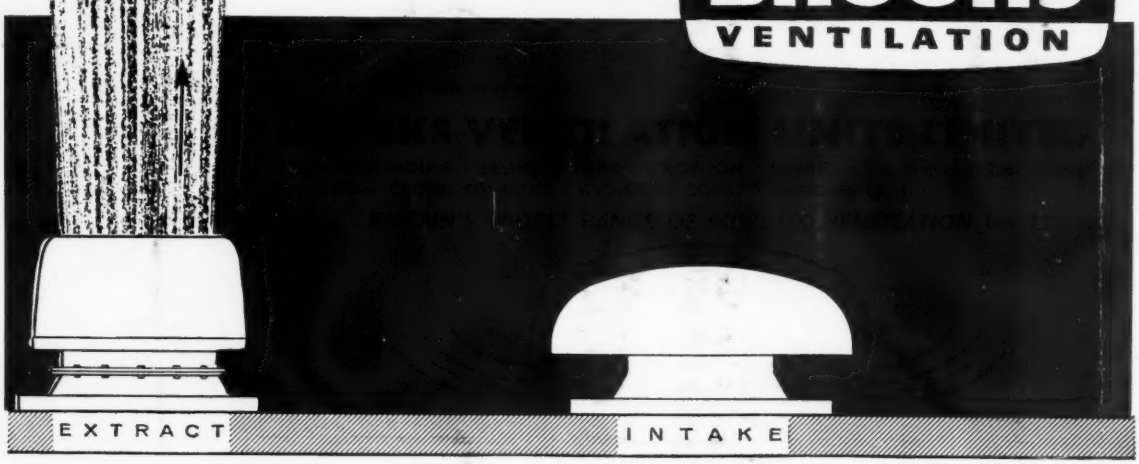
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